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THE INFLUENCE OF SHIP MOTIONS ON OPERATIONS OF SH-2F HLEICOPTERS FROM DE-1052-CLASS SHIPS: SEA TRIAL WITH USS BOWEN (DE-1079)

SPD 556-01

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
Bethesda, Maryland 20084

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by

A.E. Baitis

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SHIP PERFORMANCE DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

July 1975

SPD 556-01

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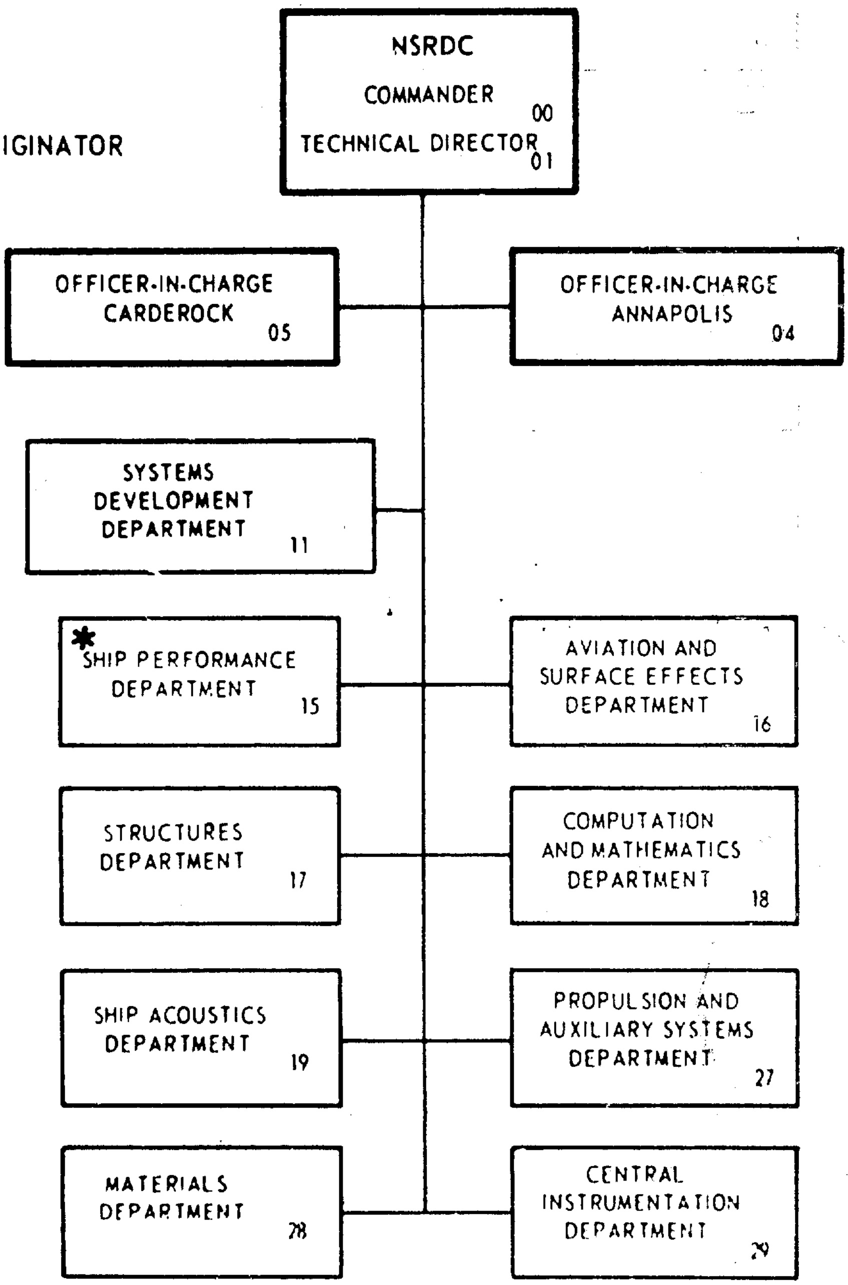

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

14

1. REPORT NUMBER: SPD-556-01

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER: 9

4. TITLE (and Subtitle): 6 THE INFLUENCE OF SHIP MOTIONS ON OPERATIONS OF SH-2F HELICOPTERS FROM DE-1052-CLASS SHIPS: SEA TRIAL WITH USS BOWEN (DE-1079).

5. TYPE OF REPORT & PERIOD COVERED: FINAL rept.

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): 10 A.E. Baitis

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Naval Ship Research and Development Center, Bethesda, Maryland 20084

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Work Unit 1-1568-009

11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Air System Command, PMA 266, PMA 266, LT. COL. L. REYNOLDS, Jefferson Plaza No. 1, Washington, D. C. 20361

12. REPORT DATE: 11 July 1975

13. NUMBER OF PAGES: 69

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): 12 77p.

15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DE-1052/SH-2F LAMPS Helicopter Operations
Helicopter Landings/Takeoffs at Sea
Limiting Wind Turbulence for Helicopter Operations
Limiting Ship Motions for Helicopter Operations
Ship Motion Measures

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 4-day sea trial was conducted with the USS BOWEN (DE-1079) in an attempt to extend the existing operating envelope of SH-2F helicopters from DE-1052-Class ships. Participants included teams from the Naval Air Test Center, the Naval Air Engineering Center, and the Naval Ship Research and Development Center (NSRDC). The present report concerns NSRDC measurements of ship motions, sea conditions, and wind

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DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE S/N 0102-014-6601

389 694

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 20 continued)

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ABSTRACT

A 4-day sea trial was conducted with the USS BOWEN (DE-1079) in an attempt to extend the existing operating envelope of SH-2F helicopters from DE-1052-Class ships. Participants included teams from the Naval Air Test Center, the Naval Air Engineering Center, and the Naval Ship Research and Development Center (NSRDC). The present report concerns NSRDC measurements of ship motions, sea conditions, and wind conditions and their relationship to the degree of difficulty experienced in aircraft operations. Air turbulence or gustiness was found to be somewhat more important for the relatively small SH-2F helicopter than ship motions although the maximum double amplitude roll of 19 degrees and maximum double amplitude pitch of 5.6 degrees did produce difficulties. However, these motions did not provide the limiting conditions under which safe SH-2F operations can be performed. The highest sea encountered during the trial was a low State 5. Additional trials in higher seas are required to establish the highest acceptable motion limits. The present results contain several important operational implications.

ADMINISTRATIVE INFORMATION

NSRDC participation in the BOWEN trial was at the request of PM-15 under Naval Air Systems Command Work Request 4-4084, Funding was provided under Work Unit 1-1568-009.

INTRODUCTION

BACKGROUND

Until quite recently, Navy helicopters were operated from relatively small, nonaviation ships such as destroyers on a "try it and see if it works" basis, without general advisory or mandatory guidelines. By 1971, however, the importance of having flight envelope limits for each combination of helicopter type and ship class was recognized and mandatory flight envelope limits were established for such combined operations.

The Dynamic Interface Program is intended to extend these envelopes to ship/aircraft-event motions that constitute more realistic limits for operational safety. The present report concerns the ship motions aspect of one specific experiment of that program, namely, a 4-day sea trial involving the LAMPS (SH-2F) helicopter and a DE-1052-Class ship, the USS BOWEN (DE-1079).

The trial was conducted several hundred miles off the coast of Charleston, South Carolina, in January 1974. The principal objective was to extend the existing flight limitation envelope for LAMPS/1052 operations and to assess a series of new landing and takeoff techniques. This was the responsibility of a team from the Naval Air Test Center (NATC) consisting of pilots, flight crew (maintenance, etc.), and test engineers.

There were two related secondary objectives:

1. Evaluation of single point tiedown system performance and loads, etc. This was the responsibility of the NATC team and a test engineer from the Naval Air Engineering Center (NAEC).
2. Measurement of ship motions and sea conditions during the trial. This was the responsibility of a two-man team from the Naval Ship Research and Development Center (NSRDC).

The active cooperation of the captain and crew of BOWEN was, of course, highly essential to the success of all aspects of the trial.

NSRDC TRIAL OBJECTIVES

More specifically NSRDC was responsible for relating its measurements of ship motions and sea conditions to the degree of difficulty experienced in performing helicopter operations.

One member of the NSRDC team was located in the flight tower and the other was below the flight deck at the NSRDC instrumentation center.

The procedures utilized for collecting ship motions data and their relation to aircraft operations had been developed earlier by NSRDC:

1. In extensive sea trials with the Interim Sea Control Ship USS GUAM (LPH-9) during which landing/takeoff operations had been investigated both for helicopters and for the British VSTOL aircraft HARRIER (AV8).*

2. In sea trials with the USS RALEIGH (LPD-1) which dealt solely with HARRIER operations.**

The development of these procedures and the rationale for the measures of ship motions employed have already been described in detail in connection with the HARRIER/RALEIGH trial.

The present report concerns the results of two basically different types of analysis of ship motion data, namely, the standard power spectrum analysis of ship motions and the aircraft event analysis of ship motions during the specific time interval of an aircraft event (i.e., takeoff/landing). Both types of analysis are required in order to relate ship motions to the degree of difficulty experienced in such events.

It is recognized, of course, that the ease or difficulty of aircraft operations is influenced by many other factors, e.g., pilot skill, the maneuverability of the basic aircraft, the relative size of the aircraft and the landing deck, and such environmental aspects as wind, turbulence, and visibility. Accordingly, these additional factors were noted or recorded in some fashion as part of the ship/sea motion measurements.

Trial results which deal primarily with the direct operation of the aircraft have been reported separately by NATC.[1] The rationale for the present emphasis on relating ship motions to the degree of difficulty in aircraft events is to use this relationship for predictive purposes for ships[2] other than the 1052 class. The rms ship motions based on standard ship motion power spectrum analysis are to be related to motion measures, i.e., event motions, that relate to the degree of difficulty associated with aircraft landings and takeoffs. Both motion measurement parameters will be discussed in the following section.

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*Reported informally by A.E. Baitis and D.A. Woolaver as NSRDC Evaluation Report SPD-52541-01 (Feb 1974).

**Reported informally by D.A. Woolaver as NSRDC Evaluation Report SPD-54241-01 (Oct 1973).

[1] Commatos, M.J. et al., "Second Interim Report: SH-2F Helicopter/DE-1052 Class Destroyer Dynamic Interface Evaluation," NATC Report FT-20R-74 (Mar 1974).

[2] Bales, S.L. et al., "Response Predictions of Helicopter Landing Platform for USS BELKNAP (DLG-26) and USS GARCIA (DE-1040) Class Destroyers," NSRDC Report 3868 (Jul 1973).

DEFINITION OF SHIP MOTION MEASUREMENT PARAMETERS

RMS SHIP MOTIONS

The rms ship motions which characterize ship responses for stable ship conditions* are defined as the standard deviation σ from the mean value of ship response. It should be recognized that this standard deviation is representative of an infinitely long time history of ship motion taken when the ship conditions (load, speed) and the environment (sea direction, height, and length) are constant. Obviously, σ for a short finite sample taken from the infinitely long response time history will differ from the true σ of that history. It has been found in ship motion work that sample lengths of 18 to 30 minutes or 200 cycles of ship motion are generally sufficient to describe the true standard deviation of the infinite response time history, i.e., will result in statistically stable ship responses.

The standard deviation is important because the short-term variations in ship response or the peak-to-peak variations (double amplitudes) or the mean peak variations (single amplitudes) of the response time history follow a Rayleigh distribution. In turn, this distribution is uniquely defined by the standard deviation. To illustrate: if 1000 successive ship response cycles were recorded and tabulated, 31 would be expected to range between 0 and 0.25σ, 87 between 0.25σ and 0.5σ, 148 between 0.75σ and 1.0σ, 33 between 2.5σ and 3.0σ, 9 between 3.0σ and 3.5σ, and so forth.

The probability associated with the occurrence of a particular level of wave height or ship response may be found by integrating the Rayleigh probability density function of wave height or ship response from zero to the desired height or response level. Table 1 presents the results of such integrations as statistical constants which relate the rms of ship responses or wave heights (1) to statistical ship response levels or (2) to the highest expected responses in a given number of cycles of ship responses. For example, the significant double amplitude of ship motion is four times the rms ship motion whereas the significant single amplitude of ship motion is one-half the significant double amplitude or twice the rms ship response. The highest expected double amplitude in 100 cycles, on the other hand, is 6.06 times the rms ship response. Note, however, that there is a rather large probability (0.63) that the highest expected value in 100 cycles will be exceeded. See Bales et al.[2] for a more detailed and thorough presentation of the statistics of ship motions.

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*Certain changes in ship speed and heading were set as the limits for stable ship conditions. These are discussed later in connection with the measured data.

TABLE 1 – STATISTICAL CONSTANTS FOR SINGLE AMPLITUDE SHIP RESPONSES AND WAVE HEIGHTS

SINGLE AMPLITUDE STATISTICS

Root mean square amplitude, rms	$1.00\ \sigma$
Average amplitude	$1.25\ \sigma$
Average of highest 1/3 amplitudes, significant	$2.00\ \sigma$
Highest expected amplitude in 10 successive amplitudes	$2.15\ \sigma$
Average of highest 1/10 amplitudes	$2.55\ \sigma$
Highest expected amplitude in 30 successive amplitudes	$2.61\ \sigma$
Highest expected amplitude in 50 successive amplitudes	$2.80\ \sigma$
Highest expected amplitude in 100 successive amplitudes	$3.03\ \sigma$
Highest expected amplitude in 200 successive amplitudes	$3.25\ \sigma$
Highest expected amplitude in 1000 successive amplitudes	$3.72\ \sigma$

DEFINITIONS

σ^2 = Statistical variance of time history

N = Number of amplitudes

CONSTANT = $\sqrt{2}\ (\ln N)^{1/2}$, where CONSTANT relates σ to the highest expected amplitude in N amplitudes.

NOTES:

1. The highest expected amplitude in N amplitudes is the most probable extreme value in N amplitudes. This value may be exceeded 63 percent of the time.
2. To obtain wave height or double amplitude statistics from rms values, multiply single amplitude constants by 2.0.

State	Ranges of Significant Wave Heights $(\tilde{\zeta}_w)_{1/3}$ ft
1	0 – 1.9
2	1.9 – 4.1
3	4.1 – 5.7
4	5.7 – 7.4
5	7.4 – 13.0
6	13.0 – 20.8
7	20.8 – 40.3
8	40.3 – 61.6

AIRCRAFT-EVENT-RELATED SHIP MOTIONS

The two measures of ship motions that relate to the degree of difficulty in aircraft events are defined in Figure 1. The first consists of the largest double amplitude (or max-min value) that occurred within a given event.

Note from Figure 1 that the double amplitude may be equal to, greater than, or–occasionally–less than the instantaneous value. The double amplitude is considered to represent the motion value in an aircraft event which a pilot will perceive and to which he will respond. For example, if the double amplitude that occurred during a takeoff were to represent, say, roll angle or lateral acceleration, the pilot would apply sufficient directional control to compensate for the disturbing forces induced on the craft by ship motions. Thus, the maximum double amplitude in an event is regarded as a measure of the extent of difficulty encountered by the pilot due to ship motion.

The second measure of ship motion considered is the most important value of the instantaneous ship response for the type of aircraft event considered. For a takeoff, the first instant of the event when the aircraft landing gear starts to unload is defined as the instantaneous ship response of concern. Similarly for a landing, the last instant when the aircraft becomes fully supported by the ship is the instantaneous response of concern.

It is expected that the pilot may have more trouble in controlling this second measure of motion-related difficulty. Furthermore this instantaneous value may be critical for the physical considerations involved in the successful completion of the aircraft event. For example, the instantaneous value of ship motions at the time the aircraft is in the process of becoming fully supported by the ship is clearly more meaningful (skids may occur during this critical time) than the maximum double amplitude in the entire event.

SHIP AND HELICOPTER PARTICULARS

Table 2 lists the particulars for BOWEN and Table 3 those for the helicopter and flight deck.

TABLE 2 – SHIP PARTICULARS

Length between Perpendiculars, feet	415.0
Maximum Beam, feet	46.5
Maximum Hull Draft, feet	15.0
Maximum Sonar Dome Draft, feet	24.5
Displacement, Full Load, (DE 1058), long tons	3931.0
Baseline to Vertical Center of Gravity (KG), feet	17.1
Vertical Center of Gravity to Metacenter (GM), feet	5.2

Note: BOWEN is fitted with antiroll fins, but these were used during only one flight (second flight on the third of the 4-day trial). Thus it was not possible to establish either the effectiveness of such fins or their potential for improving aircraft capability to land, take off, or traverse the landing platform. This determination would have doubled the length of the trial and was thus clearly beyond the scope of the test plan.

TABLE 3 – PARTICULARS FOR HELICOPTER AND FLIGHT DECK

SH - 2F AND DE 1052

Helicopter Length Overall	52 ft 7 in.
Helicopter Average Gross Weight	12,000 lb
Helicopter LCG	Station 171 – 172
Helicopter Rotor Diameter	44 ft
Distance between Main and Tail Landing Gear	16 ft 9 in.
Distance to top of Rotor Head	13 ft 7 in.
Distance between Outside Main Landing Gear Wheels	11 ft 7 in.
Flight Deck Width at Bull's-eye	39 ft 9 in.
Clearance between Main Rotor and Hangar	10 ft

Figure 2 is a sketch of the BOWEN landing platform. There are two standard approaches to the ship, namely, port and starboard. The port approach was generally employed when the left-seat (command) pilot flew the helicopter into the deck, and the starboard approach was utilized when the right-seat pilot controlled the craft. The nonstandard or cross-deck approaches and takeoffs evaluated as part of the BOWEN trial are also illustrated in Figure 2.

MEASUREMENTS AND OBSERVATIONS

BOWEN motions were measured on the centerline of the ship one deck below the flight deck and directly under the landing target. The NSRDC instrumentation station was equipped to measure pitch, roll, yaw/ship course, and accelerations in the vertical, lateral, and longitudinal directions.

Acceleration sensors were mounted on a gyro-stabilized platform derived from a Mark 4 Mod 0 gunfire control model. This so-called "stable table" has been used consistently for many years by NSRDC to measure ship motions* and was modified in the late 1950's. (The NSRDC electronic measurements of pitch and roll were supplemented by readouts from bridge-mounted inclinometers marked by the flight engineer.)

Ship speed and course were taken by means of repeaters from the ship's own sensors. Wave height was measured by a Datawell buoy which was launched from the ship at zero speed and tethered to it by means of a 300-foot-long line. This particular buoy is a standard weight-height-measuring instrument which has won international acceptance by oceanographers active in the field of wave measurements.

Time code signals and electronic event channels were utilized for time correlations (1) between the instrumentation mounted in the helicopter and other ship/aircraft sensor instrumentation and (2) between the ship and the helicopter itself. The event channel was operated manually by the NSRDC engineer stationed in the flight tower.

Time correlation between ship motions and helicopter measurements was accomplished by relating the ship to the helicopter at two distinct periods in the landing or takeoff sequence. The start of the event (say, takeoff) was marked by activating an electrical switch as the helicopter wheels started to lift, i.e., as the tires unloaded from the deck of the ship. The end of takeoff was similarly marked when the last part of the helicopter had crossed the edge of the deck. Figure 3 demonstrates a typical helicopter landing sequence.

At the NSRDC instrumentation center below the flight deck, attempts to mark aircraft events by observing them on a television monitor were unsuccessful for two reasons. First, the perspective and view of the aircraft near and on the flight deck were inadequate to give a clear indication of when the craft crossed the flight deck, and either left or came to rest on it. Second, the remote viewing station complicated communications with the other member of the test team and also precluded observations of the direction and state (growth and decay) of the sea relative to the ship.

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*Described by S.R. Gunderson and L.C. Ruth in NSRDC Evaluation Report SPD-515-H-01 (Mar 1973).

The remote viewing did prove valuable, however, in that it enabled the ship motion record to be marked manually whenever the helicopter slid on the deck (no provision had been made for electrically recording the start-stop sequence).

In addition to marking the aircraft events, the NSRDC observer in the flight tower noted the direction and state of the sea and recorded factors which identified a particular aircraft event, i.e., time of day, speed and direction of the wind, type of aircraft manéuver, and pilot comments including their qualitative ratings of the ease or difficulty of an event. (These ratings are termed pilot rating scale—PRS). The observer also added his own comments on the timing of the event relative to the sea and ship motions and gave a general qualitative evaluation as to how difficult (rough or smooth) the event appeared from the ship.

Most data were recorded both on an eight-channel BRUSH chart recorder and a fourteen-channel FM analog tape recorder. Details of calibration procedures are given in Appendix A. Additional information on the instrumentation specifications valid for NSRDC measurements during the BOWEN trial is similar to that given in Appendix A of the informal report by Gunderson and Ruth (see footnote to page 8).

PROCEDURES FOR ANALYZING DATA COLLECTED BY NSRDC

The collection and evaluation of data were specifically intended to answer such questions as:

1. How successful are helicopter pilots in avoiding landings or takeoffs during the worst cycles of ship motion in the short time segment (e.g., 3–5 minutes) within which an aircraft event must occur?
2. What levels of ship motions appear to present problems?
3. Which motion component, or group of components, appears to present the greatest difficulty in the aircraft landing/takeoff cycle?

As already indicated, two basically different types of analysis were employed for the ship motion data. The first, the standard power spectrum analysis of ship motions, provided a valid statistical description of the BOWEN motions and the sea conditions under which the trial was performed. The second, the aircraft event analysis, utilized ship motion and aircraft correlation techniques to relate the degree of difficulty due to ship motions to the standard statistical description of these motions established in the first type of analysis.

It should be noted at this point that the present state of the art in ship motion theory does allow for accurate predictions[3,4,*] of standard statistical measures of ship motions, e.g., both significant ship motions and their time histories. Yet there is presently no known method or theory for relating predicted ship motions[2] to the three specific ship/aircraft interface problems enumerated above.

The present effort was therefore aimed at establishing this relationship between ship motions and the degree of difficulty that they cause aircraft operations at the air/ship interface. References 3 and 4 contain several specific examples of ship motion predictions based on measured model- and full-scale data.

Since the procedure used by NSRDC was concerned with establishing BOWEN motions during the entire time period that flight operations were underway (flight quarters for ship and trial personnel), ship motions were recorded continuously during helicopter flights. Figure 4 demonstrates this measurement pattern over the entire 4-day trial period as a series of short, broad, dark lines. The length of a line is directly proportional to the duration of a particular flight.

In this context, it should be noted that the data within each flight were marked prior to reduction in accordance with the two aforementioned basic types of analysis performed, namely, power spectrum analysis and aircraft event analysis.

The power spectrum analysis was performed when ship conditions were stable. In other words, there was a limit on the variation of ship speed (±1.5 knots) and heading (±27 degrees)** during the analysis time interval. Figure 5 was prepared to illustrate the data pattern of analysis within a given flight. The pattern shown there is an expansion of the line representing Day 2 in Figure 4. More specifically, Figure 5 presents the data pattern for Flight 7 of the trial (Flight 3 of Day 2). It is clear from Figure 5 that five distinct periods of stable ship conditions were encountered during this particular flight. Each combination of ship speed and heading encountered during these five intervals resulted in different rms values of ship response; see Table 1.

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[3] Zarnick, E.E. and J.A. Diskin, "Modeling Techniques for the Evaluation of Anti-Roll Tank Devices," Third Ship Control Symposium, Bath, England (Sep 1972).

[4] Baitis, A.E. and R. Wermter, "A Summary of Oblique Sea Experiments Conducted at the Naval Ship Research and Development Center," Appendix B of the Seakeeping Committee Report, 15th International Towing Tank Conference (1972).

*Reported informally by A.E. Baitis et al. in NSRDC Evaluation Report SPD-518-H-01 (Mar 1973).

**Ship motion rms values are regarded as statistically stable if two samplings for equivalent time segments at the same physical conditions (wave height, ship speed, and ship heading) yields approximately the same values.

However, the primary purpose of the BOWEN trials was not the study of ship motions and so the time periods for which stable ship conditions were obtained varied widely, i.e., from 4 to 42 minutes. As already indicated, 18- to 30-minute test periods are generally required to obtain statistically meaningful data. Nevertheless, motion results were calculated for *all* stable ship motion periods even though some rms values are not necessarily statistically stable.*

The time duration for stable ship conditions, i.e., constant speed and course, are given in Table 4 together with the corresponding numbered aircraft events. It is noteworthy that aircraft events did not always occur after ship speed or course had stabilized. In fact, stable ship conditions did not necessarily occur until some time after the start of an NSRDC data run. For example, note for Flight 1, Day 2, that seven intervals of stable ship conditions obtained during Runs 9 and 10. In all, there were 25 aircraft events during Flight 1, but only 23 of them are contained within the seven intervals.

Reduction of data for ship motion/aircraft correlation was performed for every single aircraft event. Thus, waveoffs which occurred during landings and specific intervals during which helicopter single point tiedown evolutions were performed have all been treated in the same fashion. Each individual pair of landings and takeoffs was generally performed under different flight conditions, i.e., different relative wind speeds and directions, different approach or takeoff directions, different landing and takeoff techniques, and thus different operational capabilities of the helicopter. The individual events are denoted as vertical arrows which start on the flight time scale in Figure 5. These individual events were numbered and related to the flights and specific stable-condition intervals within that flight in Table 4. Summary listings (Tables 5a–5d) were prepared for the double amplitudes and instantaneous values of ship motions for all individual aircraft events in a given trial day. These listings relate the specific motion levels during aircraft events that occurred at the various ship motion conditions presented in Table 4.

MEASURED SEA, SHIP, AND WIND CONDITIONS

SEA CONDITIONS

Figures 4 and 6 show the sea conditions that prevailed throughout the trial in terms of significant wave height (see Table 1 for definition), maximum wave heights recorded during

*Ship motion rms values are regarded as statistically stable if two samplings for equivalent time segments at the same physical conditions (wave height, ship speed, and ship heading) yield approximately the same values.

the individual wave height runs, and wave height spectra. It may be observed from these measurements that seas were equal to or greater than a high State 4 for the majority of the aircraft events. In addition, the wave height spectra for Runs 8, 12, 17, and 21 shown in Figure 6 indicate that there appeared to be a single predominant sea rather than a sea plus swell as, e.g., in Run 15 of Figure 6.

SHIP MOTIONS

Figure 7 presents the maximum variations in significant ship responses (as defined in Table 1) within a given flight as well as the wave heights that produced these motions. Unless otherwise noted, all responses are given as double amplitudes. These significant ship responses were calculated from the individual sections of response time histories during which ship speed and heading were stable. There were generally several such intervals during a flight, and each interval generally corresponded to different stable conditions of ship speed and heading. Both the largest and smallest significant ship responses within a flight are shown in Figure 7 to document this range of response levels. The reasons for these response variations and their implications for aircraft operations will be discussed later.

The greatest measured variations in significant ship responses during a particular flight were 1.8 degrees for pitch, 5.8 degrees for roll, 4.7 feet for vertical stern motion, and 0.07 g for lateral acceleration. The flights during which these ranges of ship motions were recorded are shown in Figure 7 as short, wide, black lines. The length of these lines is proportional to the length of the flight in a fashion similar to Figure 4. Ship motions recorded while the ship was hoved to in order to measure wave height are shown as open circles in the individual graphs of ship responses. Pitch and pitch-associated stern motion are also shown in the figure together with roll and roll-associated lateral acceleration.

Although the ship responses generally followed the trend for wave height, there was a difference in responses between the second and fourth trial days; the highest wave heights recorded on those days were respectively 9.3 and 7.5 feet. The largest significant lateral acceleration (0.16 g) was measured on the second day, but the largest significant roll (12.8 degrees), the largest significant pitch (5.36 degrees), and the largest significant vertical stern motion (16.8 feet) were all recorded within a 1-hour period on the fourth day.

The fact that all the largest values for these different measures of ship response did not occur in the same seas demonstrates that the frequencies of maximum lateral accelerations are different from those for maximum roll, pitch, and vertical stern motion. Thus the ship operator cannot simultaneously minimize these four responses.

WIND CONDITIONS

The true wind speed and direction are tabulated in the tenth and eleventh columns of Table 4. These computed values were based on the measured ship speed and heading and the manually recorded relative wind speed and direction as measured by the ship anamometers and displayed in the flight tower. The manual recording of relative wind was performed by the NSRDC engineer in the flight tower at the time of the individual aircraft events.

The daily average wind speeds calculated from Table 4 indicate that aircraft events on the first and fourth days of the trial occurred in average true winds of about 15 knots and that those on the second and third days occurred in average true winds of 24.4 and 16.6 knots, respectively. Thus aircraft events on the second day occurred during the highest, average true wind speeds encountered during the trial. The highest wind speed of all (31.3 knots) was measured during the third flight of the second day; a speed of 30.6 knots was recorded during the first flight of that day. These wind conditions corresponded to the flight during which the highest lateral accelerations (ship motion) were obtained.

On the other hand, the lowest wind speed (4.7 knots) was recorded during the last flight of the fourth day, the event for which pitch and vertical stern motion were the largest for the entire trial. Thus it is evident that ship motions *per se* are not necessarily directly correlated to wind speed and that a knowledge of wind speeds alone is not adequate for predicting ship motions during which aircraft events are intended to be conducted. A more detailed discussion of the variables which influence ship motion levels during aircraft events is given later.

It is important to note another characteristic of the measured winds, namely, the fluctuation of wind speed and direction with time. The highest hourly fluctuation of wind speed noted during the trial (18.5 knots for Flight 8) was associated with a 22-degree shift in wind direction. But the highest hourly fluctuation of wind direction (100 degrees) noted during the trial (Flight 3) was associated with a wind speed of only 6.2 knots. Thus very large variations in wind speed and direction occurred during intervals of less than 1 hour. Wind speed and direction should be recorded in similar fashion as ship motions for dynamic interface trials such as that with BOWEN.

SHIP MOTIONS CORRESPONDING TO A TYPICAL WIND LIMITATION ENVELOPE

As mentioned in the introduction, the BOWEN trial represented an attempt to expand the existing wind limitation envelope for LAMPS helicopters operating with DE-1052-Class

ships and to assess a series of new landing and takeoff techniques.* A discussion of the methods for determining the aircraft limiting envelope is given in Appendix B in order to relate measured ship motions to the established limiting wind envelope. These trial procedure observations are also made to assess how ship motion productions may be made for specific existing or future limiting wind envelopes. No reliable method is currently available to establish this relationship.

Figure 8 was prepared to demonstrate the ship motions corresponding to a typical limiting wind envelope (preliminary) during the present trial. The graphs (roll and pitch) show this envelope as well as both the significant and the largest response double amplitudes within the aircraft event. The ship motion measures indicated on the graphs represent the result of the two types of analysis performed. Response magnitude is plotted similarly to relative wind speeds, i.e., magnitude increases with increasing distance from the center of the graph. The ship roll and pitch shown on the graphs correspond to the limiting wind test points defined by Pilot Rating Scale**, PRS, ratings of 2 or more. Unlike wind data, the roll and pitch data are connected by straight lines.

Figure 8a illustrates the ship roll measured by NSRDC at the different relative wind speeds and directions. Roll motions appeared to reach a maximum in both head and quartering winds. Ship roll generally increased as headings varied away from head seas and decreased somewhat as ship speed increased. The large roll in head winds for two particular events are unexpected and suggest contributions from either one or a combination of the following factors:

1. Waves may have been higher at these events than at others.
2. Wind waves may not have come from the same direction as the waves which, in turn, produced roll (i.e., the presence of swell).
3. Very low ship speed and relatively high true wind.

On the other hand, the large roll in beam and quartering seas is expected because the magnitude of the relative wind does not suggest a very low ship speed, and quartering winds also often correspond to quartering seas.

In general, these ship roll response curves indicate that when the helicopter was operated near its limit in head winds***, ship roll was quite small. In contrast, when the helicopter was operated near its limit in port bow and starboard beam winds, ship roll was quite large (significant roll of 12.8 degrees). It is noted in passing that 12.8 degrees represents a substantial amount of roll. In turn, such magnitudes suggest that although roll may have constituted a problem during bow and beam winds, it is unlikely to have been a problem during head winds.

*Details on the aircraft techniques have been reported in Reference 1.

**See Reference 1 for definition.

***Relative to the helicopter aligned on its landing line.

A comparison of the two types of ship motion measures shown in Figure 8a suggests that significant ship motions are generally equal to or greater than ship-induced event motions. In other words, the pilots were generally successful in landing during ship roll motions which were less than the significant ship motions.

Figure 8b gives similar information for ship pitch. Unlike roll, pitch was relatively constant (about 2 degrees significant) with wind direction. Again as with roll, the exception appeared to be in head winds relative to the helicopter. Pitch appeared to be minimal (about 0.7 degree significant) in the helicopter head wind test, suggesting that ship motions were minimal during these relatively easiest limiting conditions (head winds).

The pilots were generally successful in landing during ship pitch motion less than the significant ship motions. The exception for both pitch and roll was for quartering winds relative to the ship or beam winds relative to the helicopter.

A comparison of Figures 8a and 8b indicates that during limiting wind conditions, pitch was usually about one-third as large as roll. This does not imply, however, that pitch and pitch-associated vertical motion (or vertical acceleration) of the landing platform are less important than roll.*

The limiting wind envelope shown in Figures 8a and 8b does not necessarily represent a final envelope that has been approved by the appropriate naval commands. Rather it is a preliminary envelope selected from the NATC data files and is included here only to illustrate typical ship motions that correspond to such a limiting envelope.

At any rate, the envelope illustrated in these graphs applies for daytime port approaches and starboard launches with ship roll of 10 degrees and pitch up to 4 degrees (based on inclinometer readings).

The correlation was poor between values of ship pitch and roll as measured electronically by NSRDC and as recorded by bridge-mounted inclinometers. This discrepancy is explainable by two basic sources of error. One is associated with the basic inaccuracy of inclinometers as devices for dynamic measurements of roll and pitch, and the other is related to the timing with which the sensors are read. Both sources of error are discussed in Appendix C and illustrated with reference to the wind limiting envelope of Figure 8.

The need for more accurate measurements of pitch and roll than possible with inclinometers presents no difficulty. These can be obtained from the sensors of the gyro-stabilized navigational compass. All that is required is the installation of pitch and roll repeaters on the bridge and on the flight control tower.

*The relative importance of ship roll and pitch in aircraft landings and takeoffs can be established by a statistical analysis wherein the individual event responses are ranked in order of decreasing response. This is done later in the report.

TIME HISTORIES OF SHIP MOTIONS

Figures 9 and 10 present ship motion data collected during some of the more severe test conditions, i.e., low State 5 seas in the form of time histories. Results are shown in this .nost basic form:

1. To illustrate the general fluctuations in ship responses with time.
2. To demonstrate the importance of timing aircraft events to occur during benign ship motion conditions, i.e., lulls.
3. To document conditions that produced aircraft skids.

Only the most important ship responses are shown in the figure along with the calibrations and the polarities of the responses.

The results of a standard landing with a turn on the spot aircraft maneuver are shown as Event E-6 in Figure 9. (Figure 3 presents a pictorial record of this relatively difficult (PRS = 2.5) event.) The corresponding rms ship motions and aircraft event ship motions are given respectively in Tables 4 and 5b. This landing thus represented aircraft operations beyond limits expected of Fleet pilots.

Figure 9 also presents ship responses for an across-the-deck landing and takeoff sequence. This sequence included an unsuccessful cross deck landing attempt (E-10) that resulted in a wavcoff, as well as a subsequent repeated attempt that was successful (E-11) and the equally successful takeoff (E-12).

Figure 10 presents a similar cross deck landing sequence performed on the last day of the trial. This latter sequence is of particular importance because ship motions* caused the helicopter to skid. The sequence of events is shown on the figure for two different time scales. The more compressed time scale (top of figure) covers the skid event together with the landing that preceded it and the emergency takeoff that followed it. This same sequence is shown on an expanded time scale in the lower half of the figure.

It is quite evident that the landing occurred under conditions of particularly high roll and lateral acceleration, followed by a relatively long period of low roll motions. Although this cross deck landing was successful in that there was no damage either to ship or helicopter, the extreme effort required of the pilot (see Events 10, 11 of Flight 11, Table 5d) placed this event beyond safe operating limits for Fleet pilots.

After this hazardous but successful cross deck landing had been made, the aircraft wheels were chocked. The helicopter was then partially tied down to the deck (some but not all

*Roll, lateral and vertical acceleration.

tiedown chains were fastened) and lead ballast was loaded into the craft*. About 83 seconds after the landing and before this loading was completed, the "lull" in ship motions ended. The particularly large sequence of roll angles which followed then caused a sudden, unexpected, long skid of the entire aircraft towards the portside of the ship, and there was some likelihood that subsequent roll motions might aggravate the slide. Tiedown chains were therefore removed as rapidly as possible, and the helicopter made an emergency takeoff 21 seconds after the skid**.

It is evident from this skid and takeoff sequence that if the aircraft had not taken off when it did, the next sequence of large roll motions (roll, vertical and lateral acceleration) which began immediately after the takeoff might well have moved the aircraft over the edge of the flight deck. This particular sequence of events thus demonstrates the importance of the timing (luck) of the aircraft events relative to the ship motion and emphasizes the importance of having the helicopter securely tied to the deck during high roll conditions. Roll and the associated lateral accelerations are considered to be the ship motion components which produced the skid. Clearly, if critical stages in the aircraft events can be made to occur during lulls in ship motions, no motion-induced difficulties, such as skids, are likely to occur. The helicopter is particularly vulnerable when partially tied to the deck and also when it is supported partly by lift and partly by the ship during landings and takeoffs. The former condition is considered to be more dangerous than the partial lift situation because it takes much longer and thus exposes the helicopter to more extreme ship motions. (The value of expected ship motions increase rapidly with time. For example, the highest value expected in a 10-second interval increases by 28 percent in 20 seconds and by 41 percent in 30 seconds.) Thus, minimizing the exposure time of the helicopter during such vulnerable stages as deck tiedown pays off by reducing the likelihood that excessive ship motions will be encountered.

The relative importance of the occurrence of excessive motion cycles while the helicopter is in the air over the deck (event double amplitude) and while it is partially secured to the deck may also be inferred with limited confidence from this sequence of landing, skid, and emergency takeoff. When the event double amplitude of roll is compared to the skid-associated double amplitude of roll, both are found to be about 19 degrees. Both of these rather large roll cycles increased pilot difficulty, but there is little doubt that the skid-producing roll was the more dangerous and important of the two. Accordingly, it is concluded that roll motions while the helicopter is partially tied down tend to limit aircraft operations more than do aircraft event roll motions. It follows logically therefore that a more rapid tie-down has important potential for extending the aircraft operational limits from this ship.

*Lead ballast was used to maintain aircraft gross weight within acceptable limits during a given test flight.

**As a result of this and other high ship motion cross deck landings and takeoffs, the cross deck landing technique is not recommended for fleet use as was concluded in Reference 1.

OPERATIONAL IMPLICATIONS FROM THE ANALYSES OF SHIP AND AIRCRAFT-EVENT MOTIONS

RELATIVE DIFFICULTY OF TAKEOFFS AND LANDINGS

The aircraft events obtained under stable ship motion conditions represent a total of 90 takeoffs and 97 vertical landings. These events were ranked in order of decreasing ship motions and related to the landing incident considered as indicative of serious difficulties, i.e., waveoffs. Figure 11 and Tables 5a–5d summarize the double amplitude ship motions that relate to the individual aircraft events. In the interest of brevity, only the highest 30 events ordered by pitch, vertical acceleration, roll, and lateral acceleration double amplitudes are shown.

The vertical scales for the individual graphs in Figure 11 represent the largest double amplitudes in the aircraft event (see Figure 1) ranked in order of decreasing ship motions; the horizontal scales represent the corresponding numbers for aircraft event in the ordered sequence. It should be noted that these events are completely time independent, both from event to event and from ship motion to ship motion. In other words, the landing that constitutes the highest event for pitch (5.6 degrees) may have occurred at a completely different time from the second highest event. In addition, this highest event for pitch does not necessarily correspond to the highest event for roll (14.6 degrees), vertical acceleration (0.31 g), or lateral acceleration (0.20 g). The values for the highest events as well as the aircraft events which resulted in waveoffs are also specified in this summary figure. Waveoff events were treated exactly the same as other aircraft events.

This comparison of the relative levels of the double amplitude ship motion responses indicates that takeoff values were always less than or equal to landing values but never greater. The times associated with these events were shorter for takeoffs (average of 9.8 seconds) than for landings (average of 19.6 seconds). Accordingly, takeoffs generally occurred during no more than two complete ship motion cycles whereas landings sometimes required as many as five cycles. On the average, 46 percent of the takeoffs occurred in less than one complete ship motion cycle whereas only 23 percent of the landings were accomplished in less than one cycle.

These results may be interpreted to mean that pilots find it easier to select the proper time to take off and that they spend less time over the deck once they decide to launch. Since the level of ship motions increases rapidly with time, a quick takeoff exposes the helicopter to substantially lower double amplitude ship motions. (This result was also observed during HARRIER operations aboard GUAM.)

To conclude that takeoffs are easier than landings does not necessarily mean that pilots will be able to select lower instantaneous ship motion values in which to consciously perform

critical stages (aircraft support partially from lift and partially by the ship) of operation. In fact, a review of the instantaneous values tabulated for the individual aircraft events suggests that takeoffs occurred at greater values of pitch and roll than did landings. This implies that although the pilots attempt to land/takeoff during lulls, they are not particularly successful at simultaneously making the instant of touchdown or liftoff occur with a level deck.

The largest instantaneous values associated with landings and takeoffs were respectively 6.3 and 7.6 degrees for roll (second day of the trial) and 1.6 and 1.4 degrees for pitch (last flight of the final day of the trial).

The ordered sequence of aircraft events places waveoffs during landings at or near the top. This has important implications for ships of the 1052 class. Inasmuch as waveoffs are considered to be precursors of serious difficulties, their occurrence near the top of both the pitch (and pitch-associated vertical acceleration or motion) and the roll (and roll-associated lateral acceleration or motion) sequences indicates that both types of motions create difficulties in aircraft operations.

RELATIVE IMPORTANCE OF ROLL AND PITCH IN AIRCRAFT OPERATIONS

Note from Figure 11 that during the aircraft events, extreme pitch motions were about one-half as large as the extreme roll motions and--surprisingly--that the extreme lateral accelerations were about two-thirds of the extreme vertical accelerations. Thus lateral accelerations are relatively large for the 1052 class, and consequently roll is a more important component so far as aircraft operations are concerned than for some other ship types. For instance, Canadian experience with helicopter/ship operations and U.S. Navy experience with helicopters operating from the GUAM both indicated that pitch and its associated ship motions were more bothersome than roll.

This apparent discrepancy in the component of ship motion which produces operational difficulties is considered to be related to the angle between the longitudinal axes of ship and aircraft during critical stages of landing/takeoff. Thus ships which launch and recover aircraft with the longitudinal axis of the craft parallel to the longitudinal axis of the ship will find only pitch and its associated ship motions troublesome during landings and takeoffs. But these operations as conducted by 1052-Class ships involve substantial angles between the longitudinal axes of craft and ship. Roll and roll-associated ship motions then also become factors for which the pilot has to compensate or contend with in the critical stages of landing and takeoff.

The addition of the roll component to the motions of major concern to the pilot will substantially increase the difficulty of landing and takeoff. Moreover, it is quite impossible for the ship operator to simultaneously minimize both sets of motion components.

The results imply that either pitch or roll may independently produce difficulties or even cause cancellation of aircraft operations with the 1052 class. Accordingly, roll stabilization of this class would directly improve its capability to launch and recover aircraft.

CRITERION FOR ROLL STABILIZATION

Roll stabilization is an alternative/complementary procedure for extending the operational capability or safety of this or similar ship/helicopter combinations. A conservative roll stabilization goal or criterion can be extracted from the 1300-second interval of stable ship motion within the segment during which the skid and emergency takeoff sequence of Figure 10 occurred. The roll and lateral accelerations in this segment of Flight 11 (12.8-degree significant double amplitudes of roll) are considered conservative estimates of the most severe conditions in which unassisted, free deck landings can be made with a reasonable degree of safety. Normal landings/takeoffs under these conditions can be and were made at limits (PRS = 2.0) expected of Fleet pilots (see Table 5d, Flight 11, Events 6 and 7). It is concluded from the above data that a 12.8-degree significant double amplitude roll represents *realistic* roll stabilization goals for destroyers deploying helicopters for free, unassisted deck landings.

MOTION LEVELS THAT LIMIT AIRCRAFT OPERATIONS

Because of the very large number of variables involved, motion limits can be specified here only in terms of a range rather than on the basis of specific single values. The number of variables involved also makes a statistical approach appropriate. Two basic types of statistics can be utilized to establish limiting motion levels:

1. The pilot rating (PRS) of the difficulty of aircraft events and pilot comments following particular events.
2. Cases where ship motions and other flight conditions were so severe that the event had to be aborted.

The results of pilot ratings have been reported in Tables 5a–5d. However, they were not used for the present analysis because the waveoff criterion is considered somewhat more reliable for defining the motion levels which limit aircraft operations. It has already been indicated

that landings are more difficult than takeoffs; they take more time to accomplish and generally occur at higher ship motions (see Figure 11). In this context, then, motion levels that cause landing waveoffs are considered to be the levels that tend to limit helicopter operations.

Difficulties can be expected when motions within the aircraft event reach pitch levels from 2.7 to 5.6 degrees and roll levels from 6.4 to 14.6 degrees. The equivalent values for pitch- and roll-association motions are 0.17 to 0.31 g for vertical acceleration and from 0.12 to 0.20 g for lateral acceleration. The corresponding values of significant ship motions are 2.2 to 4.0 degrees for pitch, 4.4 to 11.1 degrees for roll, 0.13 to 0.25 g for vertical acceleration, and 0.09 to 0.16 g for lateral acceleration.

Although these levels of significant ship and event motions produced difficulties with aircraft landings, they do not necessarily represent the highest levels during which landings can be accomplished. Significant and event motions can be considered synonymous with limiting ship motions only when repeated attempts to land under the same conditions result in repeated waveoffs.

An individual waveoff indicates conditions where recognizable lulls in ship motions did not occur or could not be utilized* while the helicopter was hovering over the deck. The distinction is illustrated by Figure 12 which represents the last flight of the trial.

It is clear from Figure 12 that prior to the waveoff, ship motions during the aircraft event contained many lulls during which a landing would have been relatively simple. It seems far safer to conclude, then, that the event motion levels that resulted in waveoff were limiting motions. The relation of these event motions to significant ship motions cannot be inferred with precision at this time. More extensive ship/aircraft event data in high seas are required to refine the relationship.

Although event motions may constitute limiting ship motions so far as landing or takeoff is concerned, they are not necessarily limiting for the entire operation. For example, a different and lower ship motion limit may be necessary while the aircraft is being securely tied to the deck, or while maintenance is being performed. Thus the availability of a quick-securing mechanism and a pilot-controlled quick-release mechanism would enable the pilots to take better advantage of lulls and thus enable helicopter operations under higher ship motion conditions than observed during the trials. This assumes, of course, that pilots/deck landing crews are able and willing to make several attempts at a landing.

PILOT SKILL IN SELECTING LULLS IN SHIP MOTIONS

Pilot skill in locating lulls in ship motions can be deduced by comparing the largest double amplitude within an aircraft event with the two measures of ship motion:

1. The largest possible ship motion that the pilot could have encountered during the short time segment within which the event must occur.

*Physical reasons for a waveoff include cases where the pilots ability to perform a normal landing had been made deliberately more difficult by either attempting a cross deck landing or by degrading the flying qualities of the helicopter for test purposes.

2. The standard statistical measure of ship motions, i.e., the significant ship motions.

Figures 13 and 14 and Tables 6A–6H were prepared to demonstrate pilot success in locating lulls. Figure 13 presents pitch and roll results for both takeoffs and landings, and Figure 14 shows the associated vertical and lateral acceleration. The tables give the ordered values from which Figures 13 and 14 were prepared.

Note that even during the highest ship motions, the highest aircraft event did not necessarily occur when the significant or maximum ship motions were largest. Consider, for example, the second and twelfth events in Figure 13:

	Event Roll, deg	Significant Roll, deg	Maximum Roll, deg
E-2	12.8	11.1	15.6
E-12	7.1	12.8	19.2

Thus the occurrence of aircraft events in the random motion time history is marked by varying success in timing the events to occur during lulls in ship motions. On a few occasions, the aircraft event occurred during the worst possible period of ship motions within the 3- to 5-minute segment of stable ship conditions. Unfortunately, such incidents tended to occur for the larger motions and thus these particular aircraft events rank at or near the top of the ordered sequence.

Lulls were particularly apt to be missed during pitch and pitch-associated vertical accelerations. Note the first five events in the landing sequences of Figures 13 and 14. Here the pilots inadvertently used the worst possible motions (denoted by x on the graphs) four out of five times for pitch and twice out of five times for pitch-associated vertical acceleration. In contrast, they selected the worst possible motions for roll twice out of five times and those for lateral acceleration only once out of five. Thus lulls during roll appear to be easier to locate than lulls during pitch. Clearly, a landing aid to lessen the likelihood of missing a lull at higher ship motions would be very valuable.

SHIP MOTION DESIGN VALUES FOR SHIP/HELICOPTER INTERFACE

Standard measures of ship motions and the degree of difficulty experienced in landing/takeoff operations from a ship are useful both for the ship/aircraft operators and for purposes of ship/aircraft interface design. Data from the BOWEN trial indicate that the operators are less successful in finding motion lulls at the limiting ship motions (Figures 13 and 14) than at less severe and typical ship motions, such as those corresponding to a typical wind envelope (Figure 8). It is clear from Figure 8 that the landings and takeoffs are generally made at ship motion levels lower than the significant ship motions. However, this relationship between a statistical level of ship response* and the level at which aircraft events tend to occur cannot be used with confidence in interface design because it is exceeded quite often when operations are performed at higher ship motion levels.

At the higher limiting ship motions it appears that the operators frequently inadvertently perform the aircraft operations at the highest possible ship motions that occur within a 4- to 41.5-minute period of stable ship motions. Based on the highest five events in Figures 13 and 14 and Table 6, these extreme motion levels correspond to the highest expected ship motion in as many as 280 motion cycles. It is to be noted, however, that these highest events occurred under unrealistic operational conditions in that, they were obtained as part of a trial. Under normal operating conditons, it is considered unlikely that the ship would retain its helicopter recovery course for as long (up to 41 minutes) as it did during the trial. Thus, no matter how poorly the ship motion lull was "taken advantage of," the helicopter event would not realistically be exposed to the highest expected extreme motion in 41 minutes. For these reasons it is considered that the highest expected value in 280 cycles (3.36 rms) of motion rather than the highest expected value in 100 or 1000 cycles (3.03 or 3.72 times rms) of Reference 2 is appropriate and conservative for interface design.

CONCLUSIONS AND RECOMMENDATIONS

Eleven major conclusions and recommendations are made on the basis of the BOWEN trial:

1. Air turbulence or gustiness produced more difficulty during landing/takeoffs than did ship motions; thus, dynamic interface trials should provide for measurement of wind speed and direction in the same fashion as wave height and ship motion.

2. Helicopter operations are limited more by the difficulties experienced during landings than during takeoffs.

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*Significant ship motion response is equal to 2.00 rms for single amplitudes or 4.00 rms for double amplitudes.

3. Both roll and pitch independently produce aircraft landing difficulties, but the ship operator cannot simultaneously minimize roll, lateral accelerations and pitch, vertical accelerations.

4. The most practical and efficient way to extend the flight envelope for unassisted landing and takeoff operations is to use devices which minimize the time that the helicopter is not secured on the deck, e.g., rapid securing devices during landings and/or pilot-activated single point tiedown release during takeoff. Roll stabilization to 12.8 degree significant double amplitude roll will, of course, also extend the helicopter deployment capability of destroyer or other naval ships.

5. Waveoffs are indicators of definite occurrences of difficulties during landings, their relative scarcity indicate that the ship motion levels experienced in the BOWEN trial do not represent the highest levels during which safe landings can be made. More extensive trials in high seas are required to establish the true upper limits in which safe, unassisted helicopter landings can be performed on ships such as the DE-1052 class.

6. Additional trials should refine landing techniques during periods of high motions, particularly with regard to how ship motion lulls can be taken advantage of as reliably (safely) as possible. The feasibility of having the shipboard landings signals officer transmit to the pilot the best time to start a landing from the ship motions viewpoint should be investigated.

7. During periods when ship motions were moderate, the pilots were able to time landings and takeoffs to occur at somewhat less than significant ship motion levels. However, during high ship motions, they were much less successful in locating lulls in these motions; particularly when they involved high pitch*. For example, in one case a landing occurred during the worst possible set of ship motions in 28 minutes. Clearly, the search for and the use of lulls can result in highly variable event/ship motions. This technique, in fact, may be more dangerous than randomly selecting landing times. It is recommended, therefore, than an electronic landing aid be developed to lessen the likelihood that a lull in motion is missed when such motions reach high levels.

8. Pilots were not particularly successful in making the instant of liftoff or touchdown coincide with a level deck. A 7.6-degree roll at the instant of takeoff represents the largest value of roll observed during the trial. It is to be noted, however, that this value did not result in aircraft operational difficulties.

9. The continual variability in the roll and pitch time histories provided by the ship inclinometers unnecessarily complicated the operator's task in selecting appropriate recovery courses and speeds for prevailing environmental conditions. Accordingly, it is recommended that limiting values of ship motions be established in terms of significant ship motions so

*It is considered that the pilots inability to perceive the pitch and associated vertical ship motion results in the lower skill in selecting ship motion lulls than was the case on the USS GUAM when pitch perception was much easier.

that ship operators can have relatively stable ship pitch and roll values that can be read without question as to whether or not specific ship motions really represent "limiting motions." RMS or equivalently significant pitch and roll readouts developed from existing ship systems should be displayed both on the bridge and in the flight control station.

10. Difficulties which produce waveoffs can be expected, (a) when significant double amplitudes of pitch reach values from 2.2 to 4.0 degrees and vertical accelerations attain values ranging from 0.12 to 0.20 g, and (b) when significant double amplitudes of roll reach values from 4.4 to 11 degrees and lateral accelerations attain values ranging from 0.09 to 0.16 g. These levels do not represent the highest safe operating values. More trials in high sea conditions are required to establish the highest acceptable motion limits.

11. For landing gear, or deck strength, or similar dynamic interface design programs, it is considered appropriate to use the highest expected ship motion in 280 cycles of ship motion, i.e., 3.36 rms, rather than the highest expected in 100 cycles, i.e., 3.03 rms, or the highest expected in 1000 cycles, i.e., 3.72 rms of reference 2. This latter value is too conservative inasmuch as aircraft events would typically not experience the highest expected extreme value in 1000 cycles or even in 100 encounter cycles.

ACKNOWLEDGMENTS

The author gratefully acknowledges the diligence of Mr. Terry Applebee who performed the major portion of the work involved in the reduction of data and the assistance of Mrs. A. L. Cook who revised and edited the rough draft.

APPENDIX A
CALIBRATION PROCEDURE

The accuracy of the measured motions is, of course, always related to the original calibrations of the transducers involved. For the BOWEN trial, these calibrations consisted of very careful static pre- and post-trial calibrations of all NSRDC sensors. Roll and pitch sensors were calibrated by deflecting the stabilized platform in the "stable table" in the laboratory through a series of different angles ranging from 1/2 to 10 degrees. Results of pre- and post-trial calibrations agreed exactly. In addition, as part of the installation of the instrumentation, the stable table was referenced relative to the BOWEN compass gyroscope. As a result of this referencing, it was established that the readings of the NSRDC stable table unit were the same as from the ship's own sensor. This calibration procedure ensured the accuracy of the roll and pitch values recorded by NSRDC.

The calibration procedure for Donner accelerometers used to measure both the vertical and the two horizontal acceleration components (lateral and longitudinal) is essentially identical to that employed for the pitch and roll calibration. All units were statically calibrated by tilting them through ranges of angles that varied from 0 to 60 degrees (corresponding to acceleration values from 0 to 0.5 g for the vertical accelerometer) and from 0 to 30 degrees (corresponding to acceleration values of 0 to 0.5 g) for the horizontally mounted accelerometers. Again the agreement between pre- and post-trial calibrations ensured the accuracy of NSRDC measurements.

The wave height buoy was calibrated at the factory. At the completion of the trial, a calibration check was made by running the NSRDC maneuvering basin wavemakers while making simultaneous measurements with both the Datawell buoy and a standard ultrasonic wave height sensor. In turn, this ultrasonic wave height sensor was calibrated by moving its sensing element through a prescribed series of steps both above and below its mean level. The mean level, in turn, was several feet above the calm water level. The results of this post-trial calibration indicated that the Datawell wave buoy was operating within the manufacturer's specifications.

The speed and course measurements taken from the ship's own sensors were calibrated by manually moving the sensors through prescribed ranges with equipment that is part of the speed and course sensing system of the ship. All manual movement of the sensors was performed by an electronic technician from the crew.

Most data was recorded both on an eight-channel BRUSH chart recorder and a fourteen-channel FM analog tape recorder. Additional information regarding the instrumentation specifications valid for the NSRDC measurements on the BOWEN trial may be obtained from Appendix A the informal report by Gunderson and Ruth (see footnote to page 8).

APPENDIX B

METHODS FOR DETERMINING THE FLIGHT LIMITING ENVELOPE

Observations on methods for determining aircraft flight limiting envelopes are made (1) to relate measured ship motions to established limiting envelopes and (2) to assess how ship motion predictions may be made for specific envelopes that already exist or may be established in the future.

Current operational procedure prescribes that a helicopter pilot always use one of two approaches or departures (see Figure 1) relative to the ship. These are defined by the line-up lines which are drawn through a bullseye on the ship deck. The pilot uses these lines to reference the aircraft relative to the longitudinal axis of the ship. The alignment is employed both when the aircraft is translating toward (landing) or away from (takeoff) the ship.

Once the aircraft is hovering over the bullseye, the pilot has a choice. He may either (1) land so that the longitudinal axis of the aircraft coincides with the line-up line or (2) land by rotating (i.e., turning on the spot–TOS) the aircraft to coincide with the longitudinal axis of the ship. Similarly, he has two choices for takeoff; (1) with the aircraft located on the line-up line, he can lift off, hover, and fly off in the direction of the line-up line or (2) with the aircraft located on the longitudinal axis of the ship, he can execute a TOS at an appropriate hovering height, then fly off in the direction of the line-up line.

During landings and takeoffs, the aircraft will encounter wind speed and direction relative to the ship. Here these parameters are considered to have the same relation to aircraft responses as ship speed and directive relative to the sea have for ship responses. By this analogy, the wave height/ship relationship is regarded as equivalent to the wind gust/aircraft relationship. Of course when the aircraft crosses the deck of the ship, wind gusts or aircraft excitations are complicated by the air turbulence generated by the ship superstructure.

In order to establish a limiting envelope, the helicopter is flown on and off the ship at a variety of relative wind speeds and directions. PRS, i.e., Pilot Rating Scale, evaluations by the NATC pilots are recorded immediately following the completion of individual events. PRS ratings of 2.0 or greater are considered to be the limits that Fleet pilots are expected to meet with reasonable safety. Thus, the combination of limiting wind speed and direction for a particular type of aircraft event is defined by handling qualities of the aircraft as quantified by PRS ratings of 2 or more.

The limiting wind speeds and directions thus defined are presented on polar coordinate paper as the limiting wind envelope for the specific type of aircraft event. The associated aircraft test conditions, visibility, wind gustiness, and ship motions are also generally specified on the polar coordinate plots.

Figure 15 is an example of wind limitations on an aircraft event, in this case, the envelope for an SH-2F helicopter operating from a DLG-26-Class ship. The environmental conditions call for night operations (white lights only) during 0 to 1 degree of ship pitch and 0 to 8 degrees of ship roll.

The figure indicates that the helicopter may be launched or landed at relative wind speeds ranging from 0 to 45 knots in head winds that are 315 degrees relative to the helicopter. For this example, then, the line-up line corresponds to the 315-degree line, i.e., a line drawn at a 45-degree angle to the longitudinal axis of the ship. However, the allowable range of relative wind speeds decreases if the direction of the relative wind shifts substantially either to the starboard or portside of this line-up line. Thus, for a 25-degree shift in wind direction to starboard, the helicopter is expected to be able to operate in bow winds (i.e., 340 degrees) at a range of wind speeds from 0 to 35 knots. For a shift in relative wind direction that has the helicopter flying in beam winds, the allowable range of relative wind speeds drops to 0–5 knots.

Ideally, a helicopter wind envelope trial should be conducted when both the ship environment (sea) and aircraft environment (wind) are stable. This is obviously impractical inasmuch as even an abbreviated trial requires at least 20 individual events–landings or takeoffs. This is longer than the period during which sea conditions can be expected to remain reasonably stable and certainly much longer than stable wind conditions obtain. Typically, then, a limiting wind envelope trial will consist of a series of flights at different times, different true winds, and different sea conditions.

Even under ideal conditions, the measured significant ship motions that correspond to limiting wind aircraft events would vary at different relative wind directions because of the changes in ship speed and heading required by the value of the relative wind. This type of ship motion response could be predicted in a fashion similar to that given in Reference 2. The range of expected rms ship responses that correspond to a given wind envelope may, of course, be established by computing ship responses for a series of true wind speeds, directions relative to the sea, and sea conditions.

Figure 16 illustrates the range of ship headings relative to the sea that existed during the individual flights of Trial Day 2. These variations in headings are considered to have resulted both from the NATC test plan (relative wind specifications) and from variations in the true winds. On the other hand, Figure 17 documents the variations in winds relative to the ship that existed during the individual flights on that same day. The ranges in significant ship motions (Figure 7) recorded during individual flights are typical of the ship responses that pilots may expect when specific wind envelopes are employed for SH-2F operations with DE-1052-Class ships.

It is emphasized, however, that these measured ship responses are not necessarily the worst that might occur when these envelopes are used. Other combinations of the basic

parameters* may result in larger ship responses for any particular aircraft event and relative wind speed and direction than measured during this trial.

*True wind speeds, ship headings and ship speeds.

APPENDIX C

EXPLANATION OF THE DISCREPANCY IN VALUES OF ROLL AND PITCH AS MEASURED ELECTRONICALLY AND AS GIVEN BY INCLINOMETER READOUTS

Inclinometer readouts of ship motions are generally noted as part of the process of data collection during limiting wind envelope trials. The flight engineer or a member of the ship force notes the largest excursion from zero of the inclinometer pointer or bubble (single amplitude) during the aircraft event or near to this time, i.e., within seconds or minutes. Since a given limiting envelope consists of a series of aircraft events, there may be as many inclinometer-based pitch and roll values as there are individual test points. The largest recorded values for a given envelope then determine the range of ship motions for which the envelope is considered to be valid. For example, Figure 15 gives such motion values as 0–1.0-degree pitch and 0- to 8-degree roll for a specific wind envelope.

Figure 18 was prepared to illustrate the rather poor correlation found between inclinometer-based readouts and NSRDC electronic measurements of ship roll and pitch. The results include values which correspond to the typical wind envelope of Figures 8a and 8b. The measured double amplitudes within the aircraft event are shown on the horizontal axis of Figure 18 and the corresponding inclinometer values on the vertical axis. Straight lines are drawn as though both inclinometer and gyroscope gave the same reading for a given inclination. Data points above this lino indicate inclinometer readings that were larger than true values, and data points below the line indicate inclinometer readings that were smaller than the true values.

It is obvious from Figure 18 that the inclinometer readings are almost always too large. The error is very large for both roll and pitch and larger for roll than for pitch. The magnitude of these errors is clearly important because it approaches the actual magnitude of the limiting ship motions for the envelope illustrated by Figure 8.

Inclinometers are inaccurate for dynamic measurements of pitch and roll because they are essentially low damped pendulums or air bubble-level devices which are sensitive to longitudinal and lateral accelerations, respectively. Thus the vertical and longitudinal location of the roll inclinometer within the ship will affect the accuracy of roll readings, and the vertical and lateral placement of the pitch inclinometer will affect pitch reading accuracy. Inasmuch as vertical, lateral, and longitudinal accelerations vary with location on the ship (as illustrated by Baitis et al.).[5] it is only to be expected that inclinometer readings will be too large when large accelerations occur almost simultaneously with large angular motions.

The timing with which the inclinometers are read is potentially as large a source of error as constituted by their basic inaccuracy as angle sensors. On DE-1052-Class ships, the

[5] Baitis, A. E. et al., "Design Acceleration and Ship Motions for LNG Cargo Tanks," Tenth Symposium on Naval Hydrodynamics, Boston, Massachusetts (Jun 1974).

superstructure obstructs the view from the bridge toward the helicopter landing platform. Thus the observer on the bridge who is recording inclinometer readings may mark different times than does the observer in the flight control tower who is marking ship motions electronically. (No inclinometers were mounted in the BOWEN flight tower.) If the length of time between the end of an event and the recording of ship motions from the inclinometer is more than one ship cycle (i.e., 7 seconds), then there can be substantial differences between motions as recorded by the inclinometer and the actual extreme motions during the aircraft event.

It was noted not only during the BOWEN trial but also on previous trials with RALEIGH and GUAM, that bridge-mounted inclinometers were used (1) to determine how close to mandatory maximum operating limits the ship motions come during particular aircraft events and (2) to collect ship motion data that are considered representative of individual aircraft events. Yet all three of these ships have very accurate sensors as part of the gyro-stabilized navigational compass. The installation of pitch and roll repeaters on the bridge and flight control tower (tied in to the navigation gyroscopes) would provide flight engineers and ship forces with much more accurate pitch and roll measurements during aircraft operations than are possible with inclinometers.

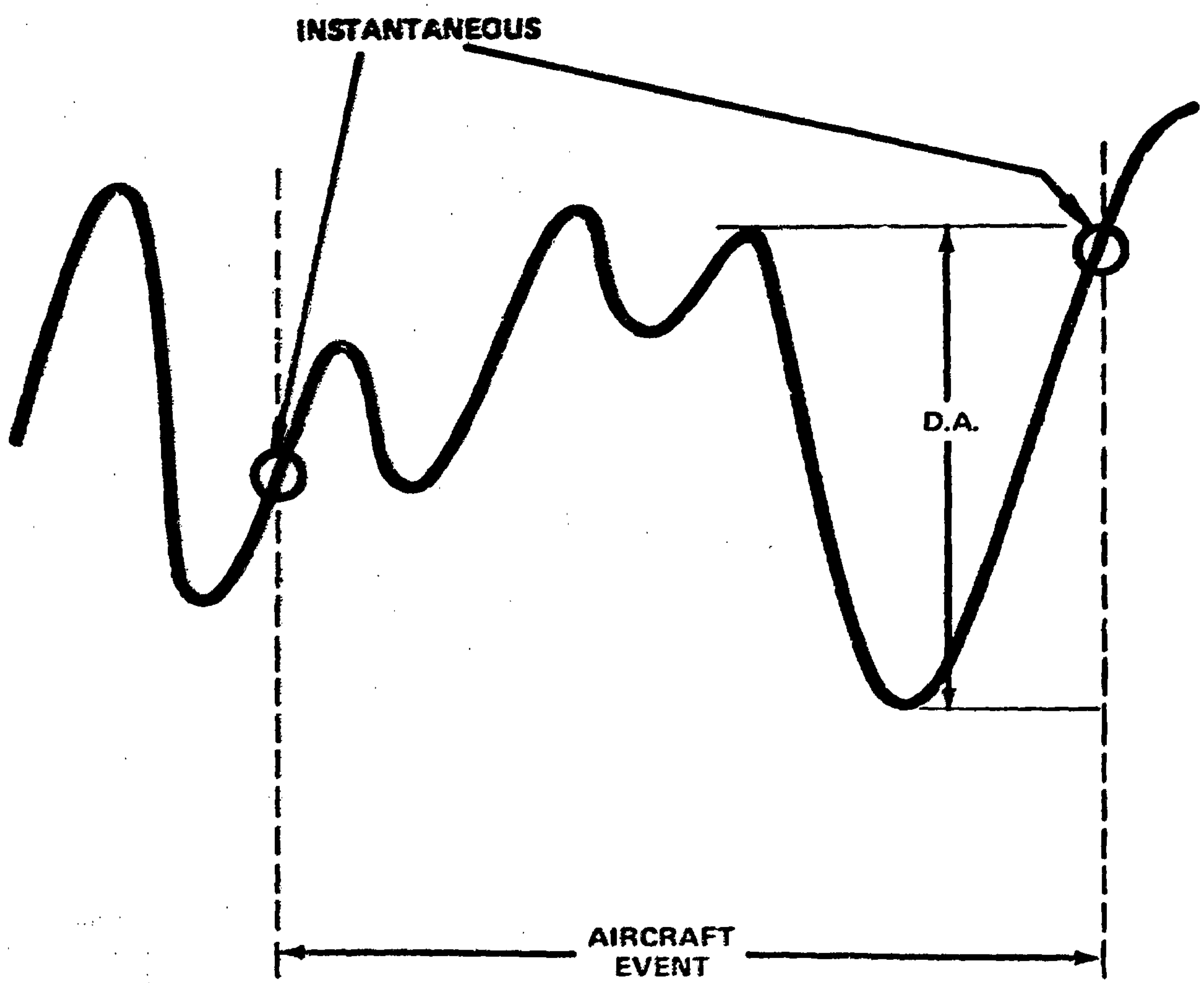


Figure 1 – Definition of the Measure of Ship Motion (Double Amplitude and Instantaneous Value) That Relate to the Difficulty of Aircraft Events

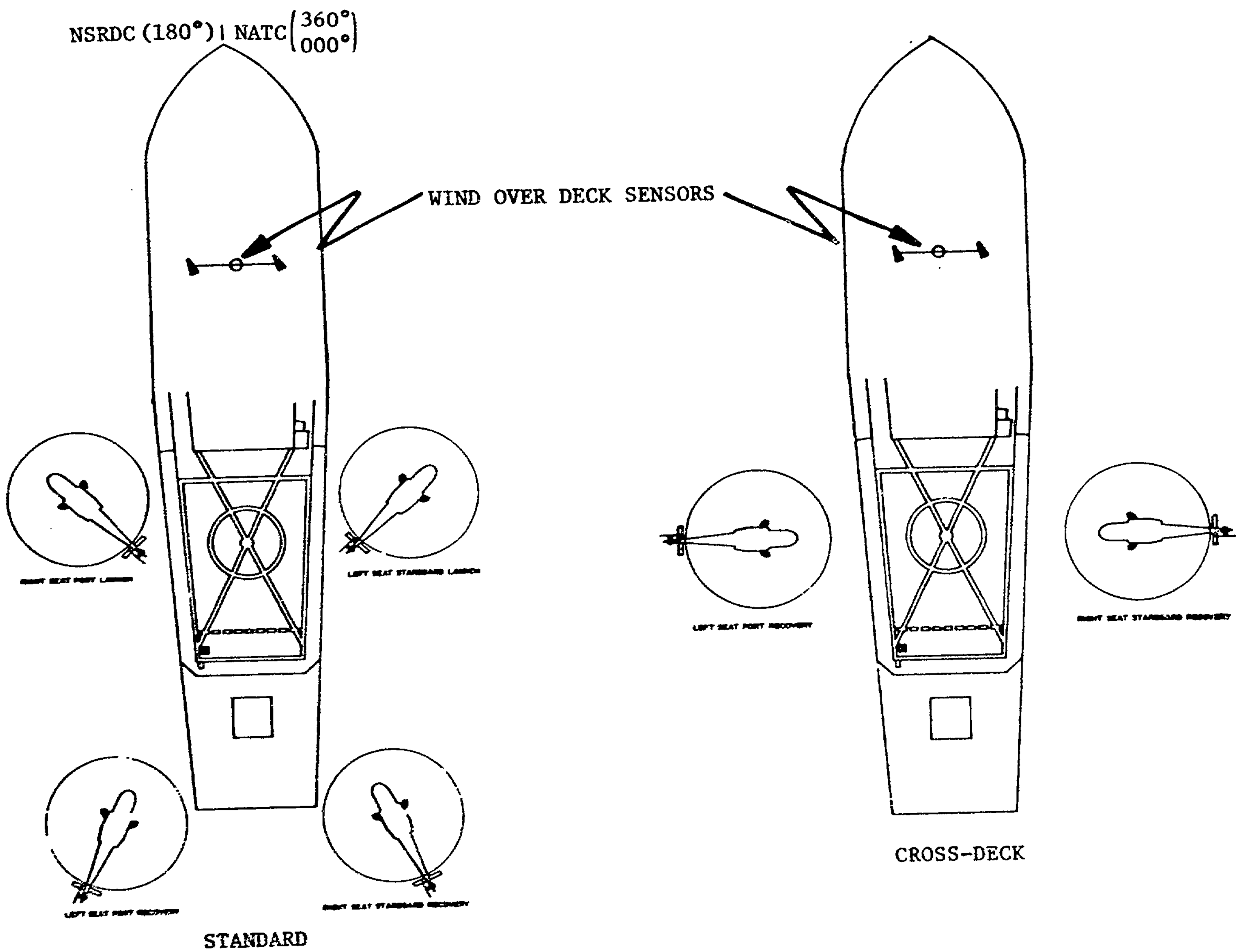


Figure 2 – BOWEN Landing Pad and Helicopter Approaches to Ship

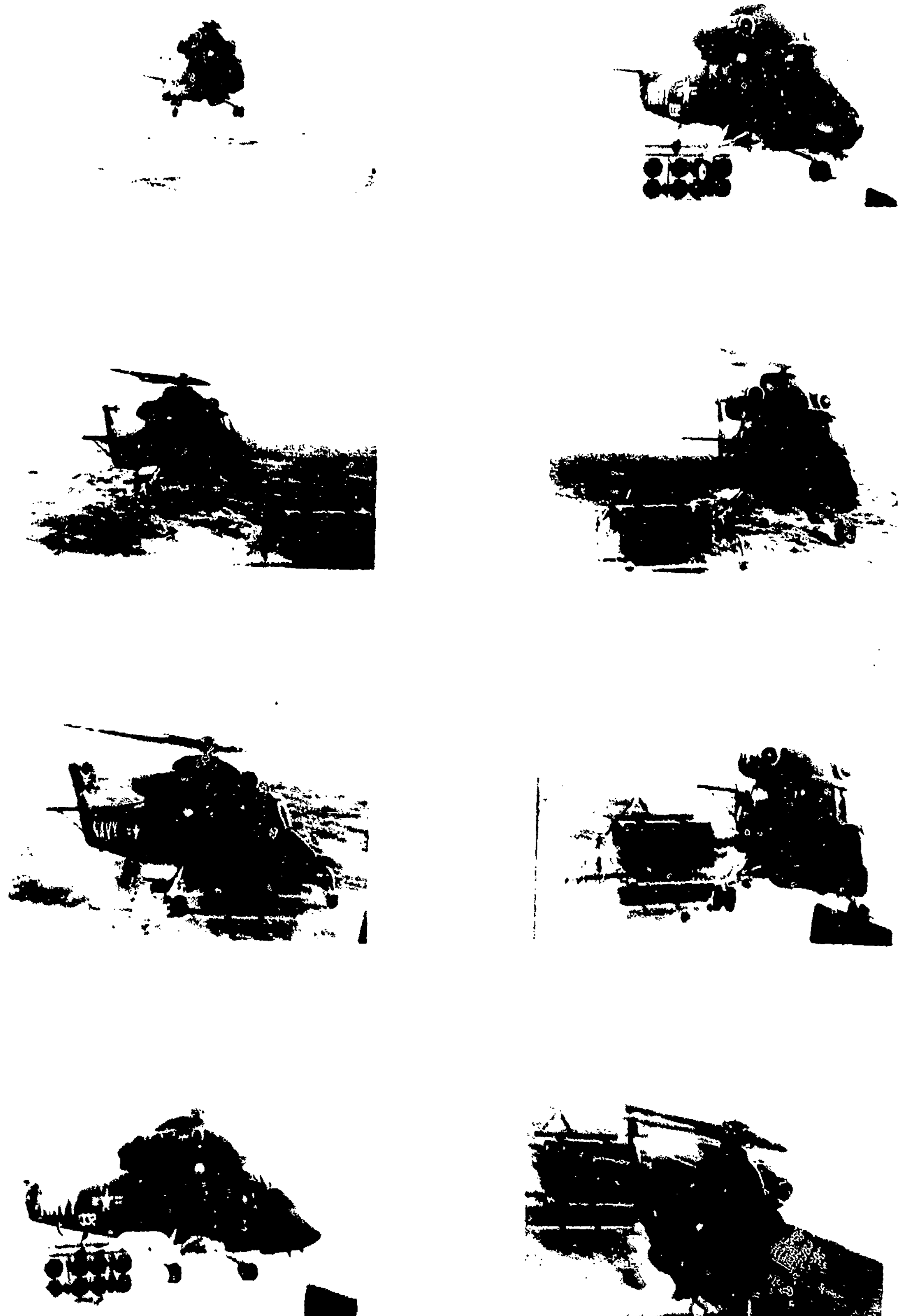


Figure 3 – Typical Helicopter Landing Sequence
(Standard starboard landing with turn on the spot, Flight 1 (5), Day 2, Run 9, E–6)

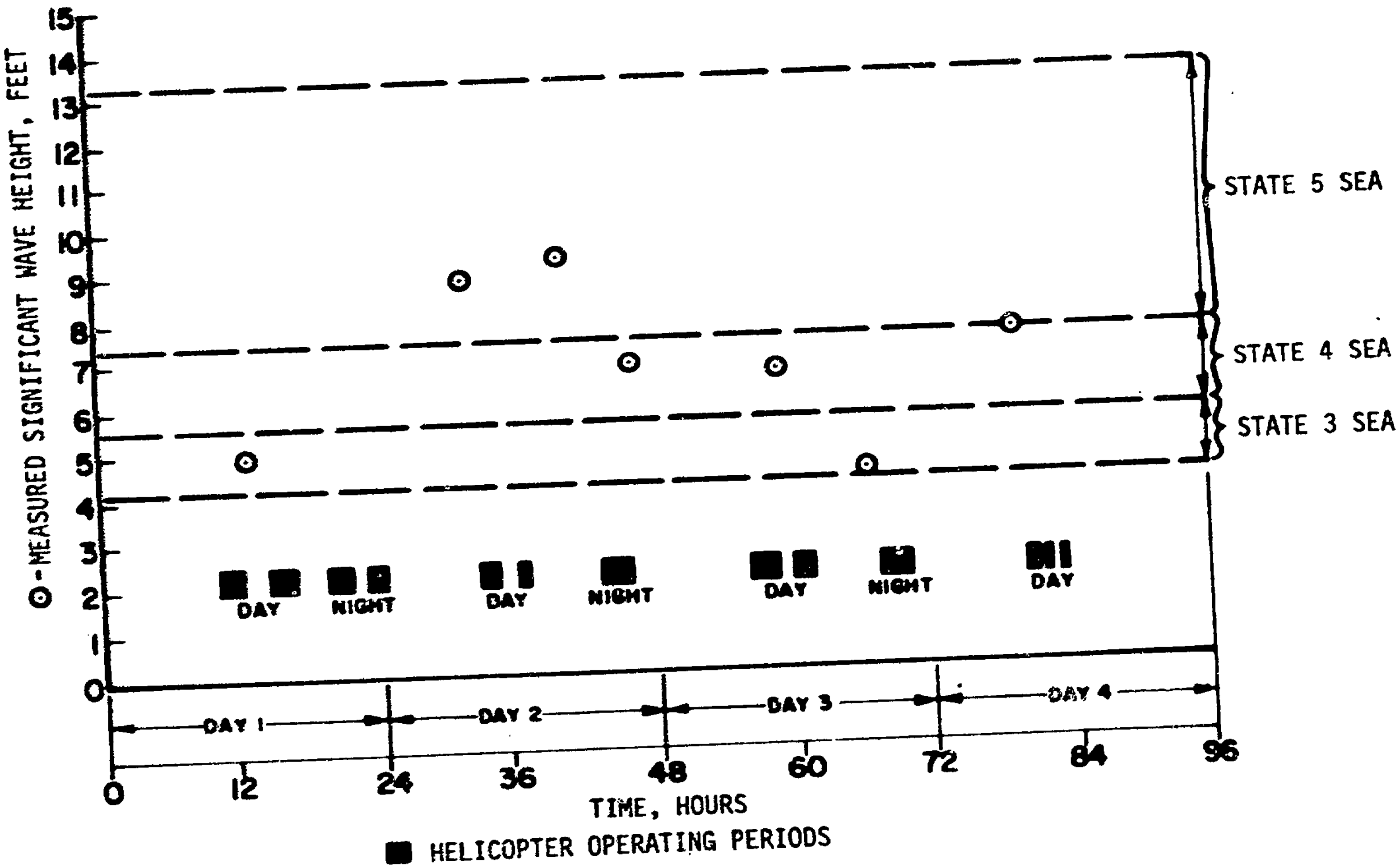


Figure 4 – Ship Motion Data Collection Periods and Sea Conditions for Entire Trial

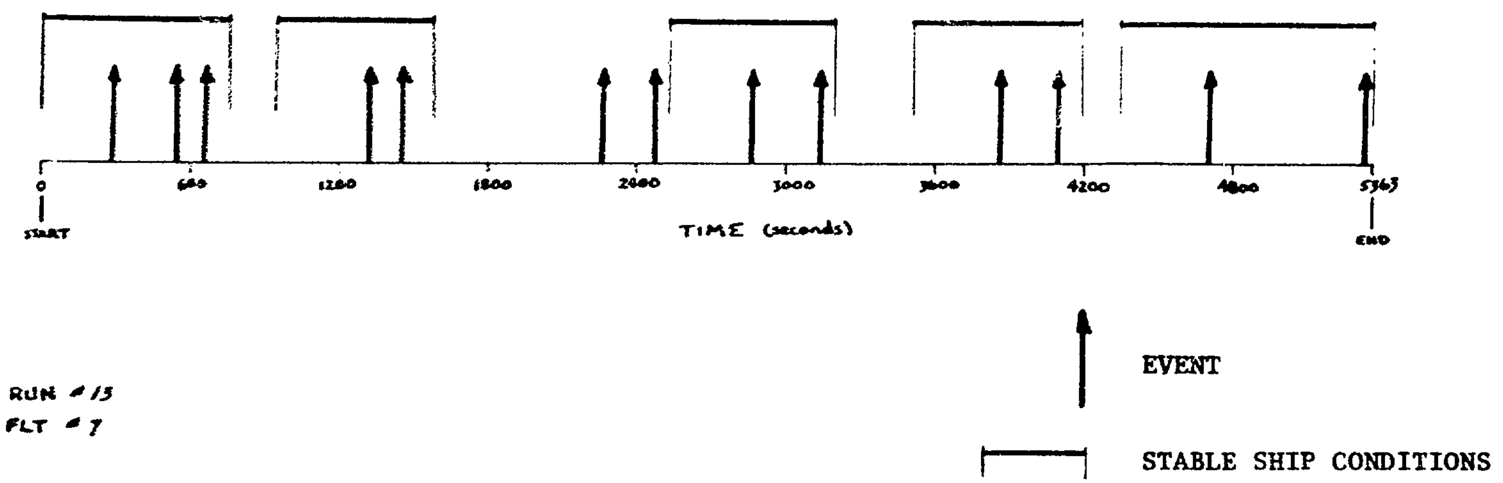


Figure 5 – Data Structure during a Single Trial Flight

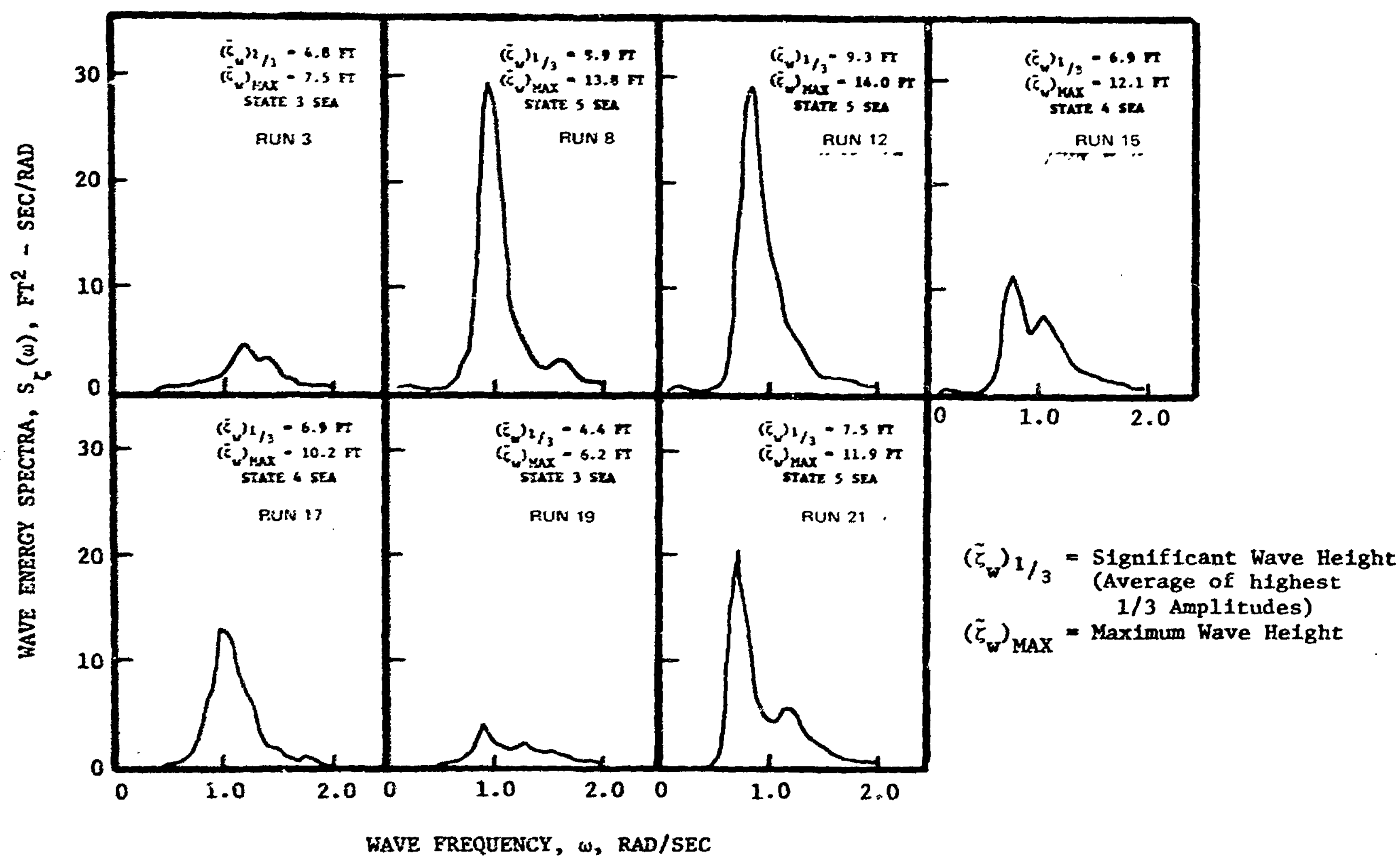


Figure 6 – Power Spectra of Measured Wave Heights

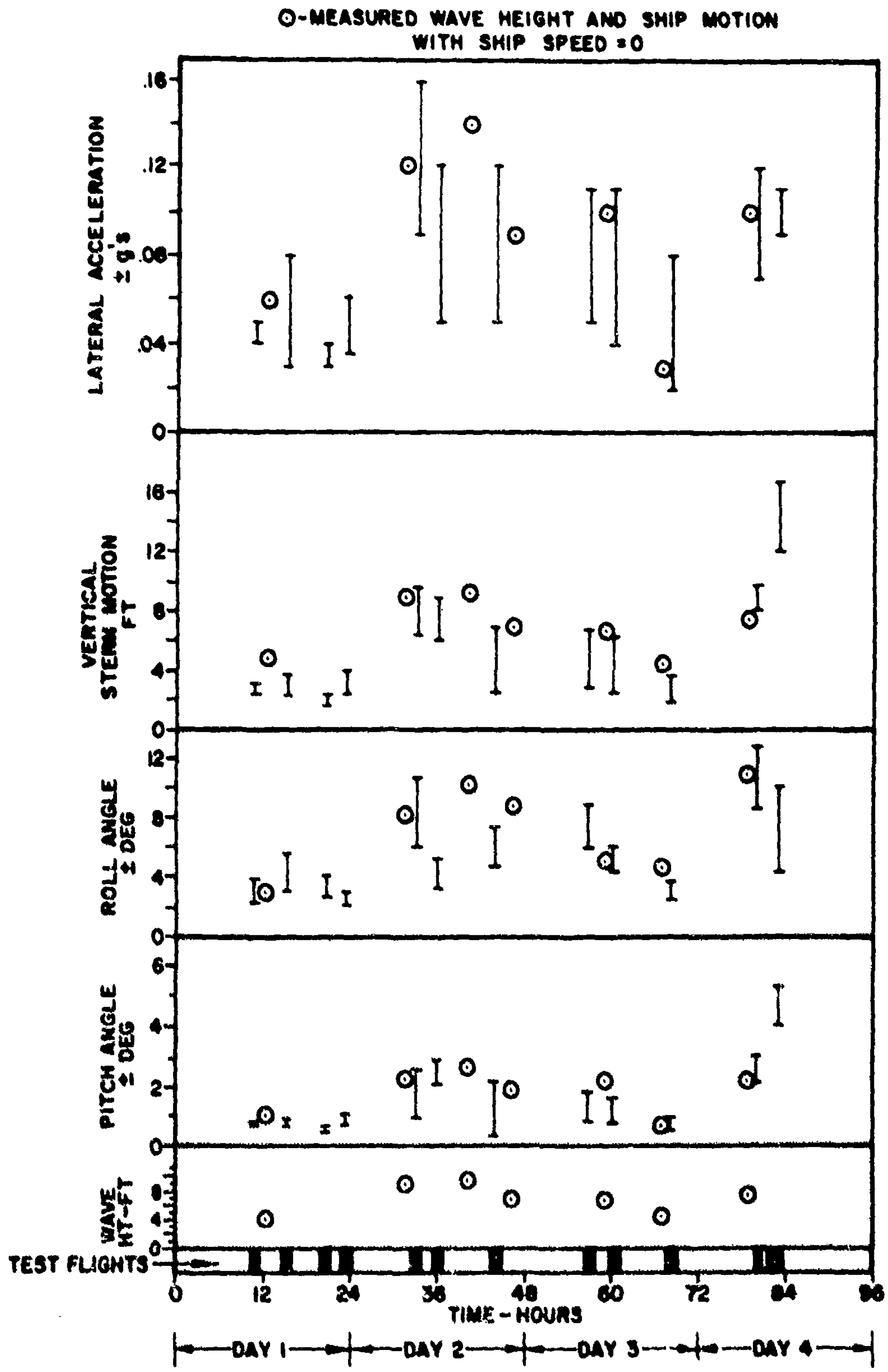


Figure 7 – Maximum Variations in Significant Ship Responses Due to Changes in Ship Speed and Heading within a Flight

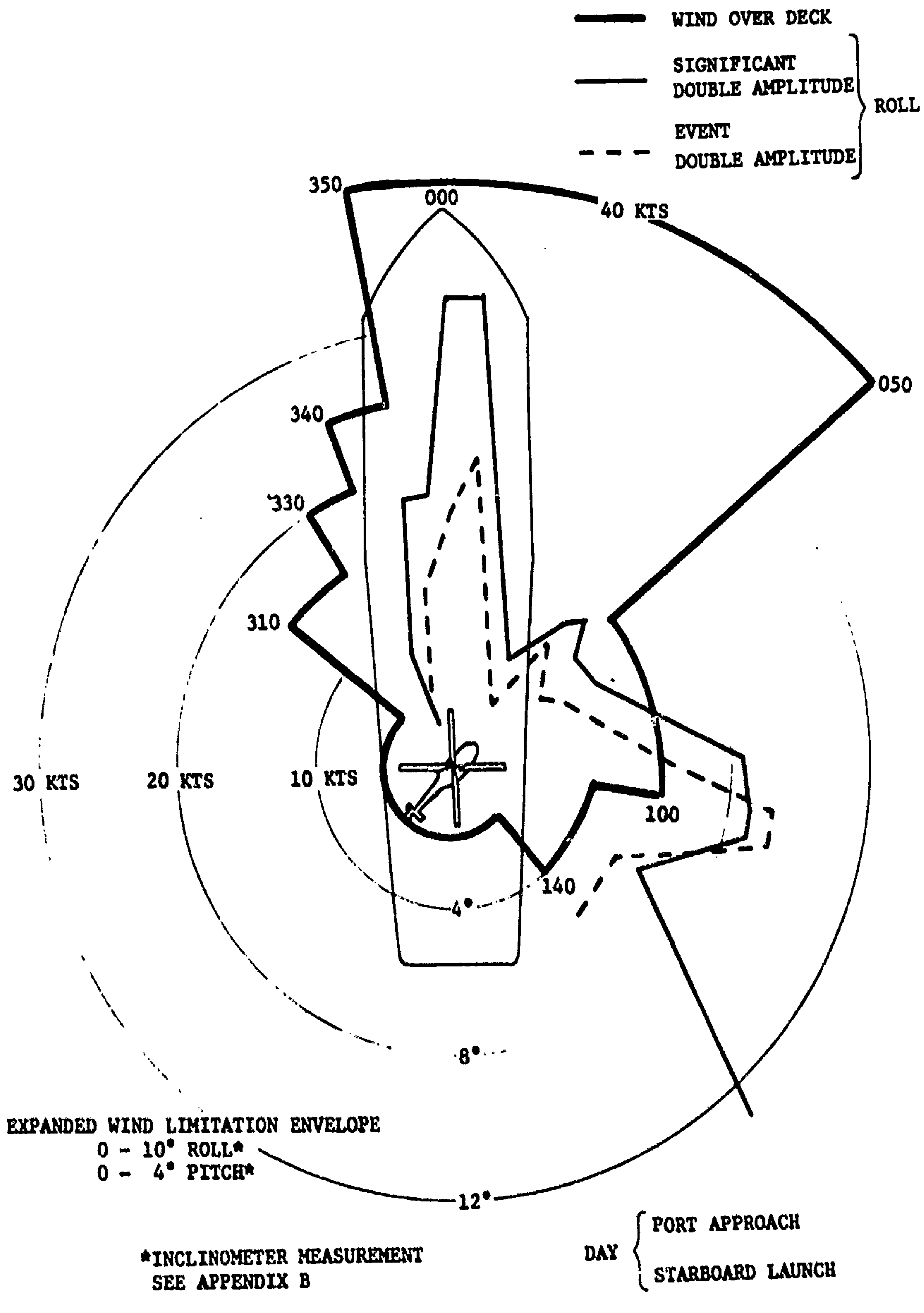
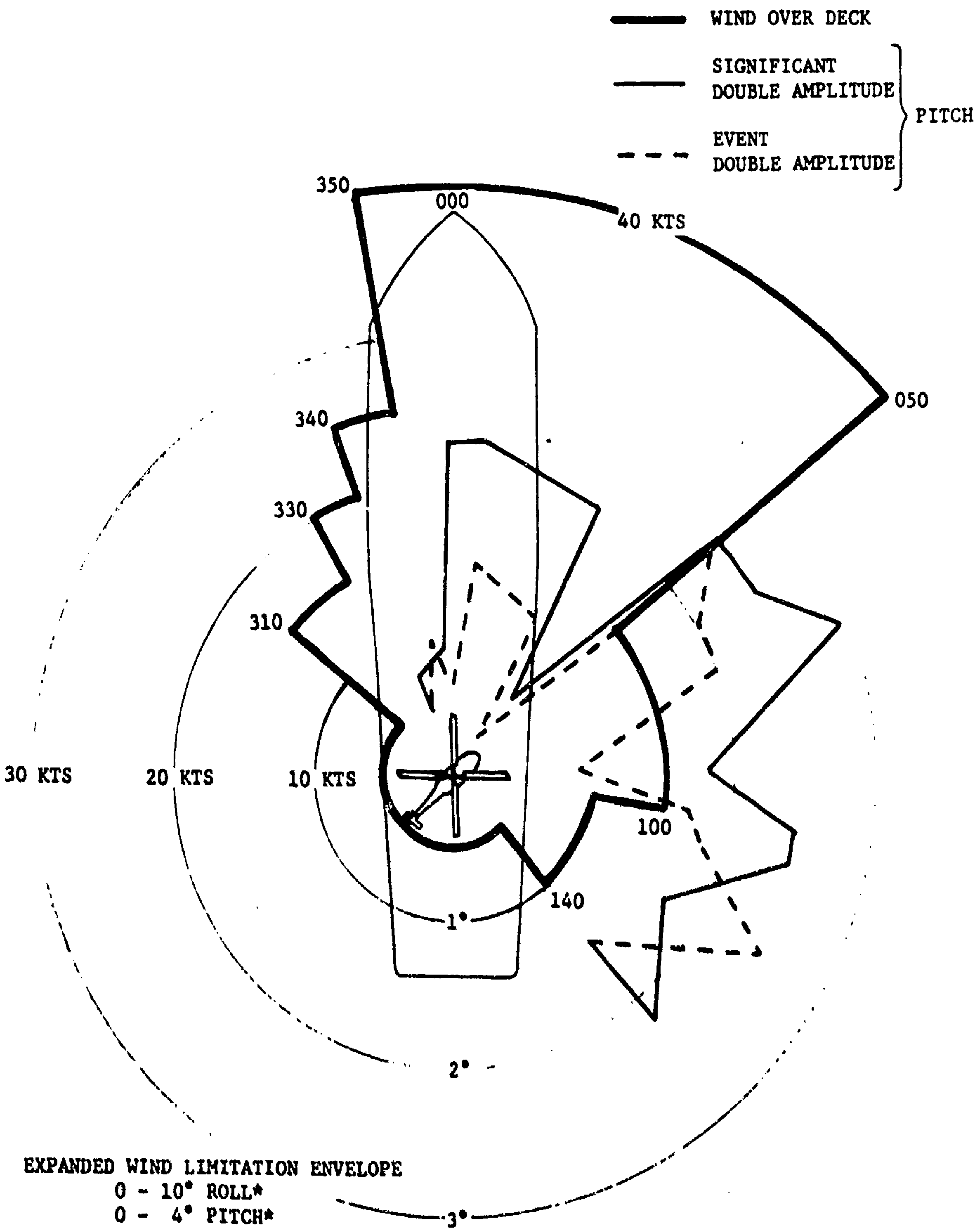


Figure 8a – Roll

Figure 8 – Ship Motions Corresponding to Typical Limiting Wind Envelope

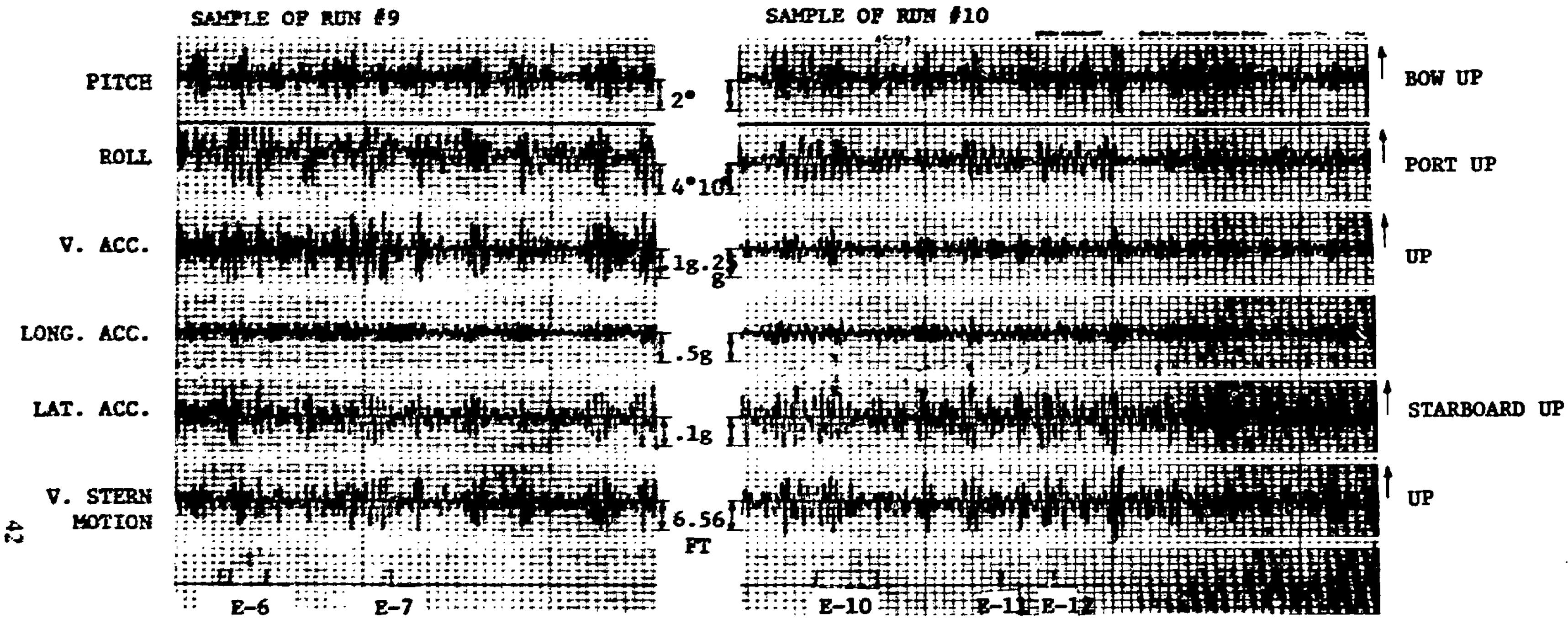


EXPANDED WIND LIMITATION ENVELOPE
0 - 10° ROLL*
0 - 4° PITCH*

*INCLINOMETER MEASUREMENT
SEE APPENDIX B

DAY {PORT APPROACH / STARBOARD LAUNCH}

Figure 8b – Pitch



STANDARD STBD
LANDING WITH
TURN ON THE
SPOT - E-6

WIND SPEED = 24 Knots
DIRECTION
REL. TO SHIP = 300°

SHIP SPEED = 9.4 Knots
DIRECTION
REL. TO SEA = 133°

FOR PHOTOGRAPHIC COVERAGE OF E-6
SEE FIGURE 3
FOR DETAIL STATISTICAL OR RMS SHIP MOTIONS SEE TABLE 4
FOR DETAIL EVENT SHIP MOTIONS SEE TABLE 5B

CROSS DECK LANDING AND TAKEOFF SEQUENCE
ATTEMPTED LANDING AND SUBSEQUENT WAVEOFF - E-10

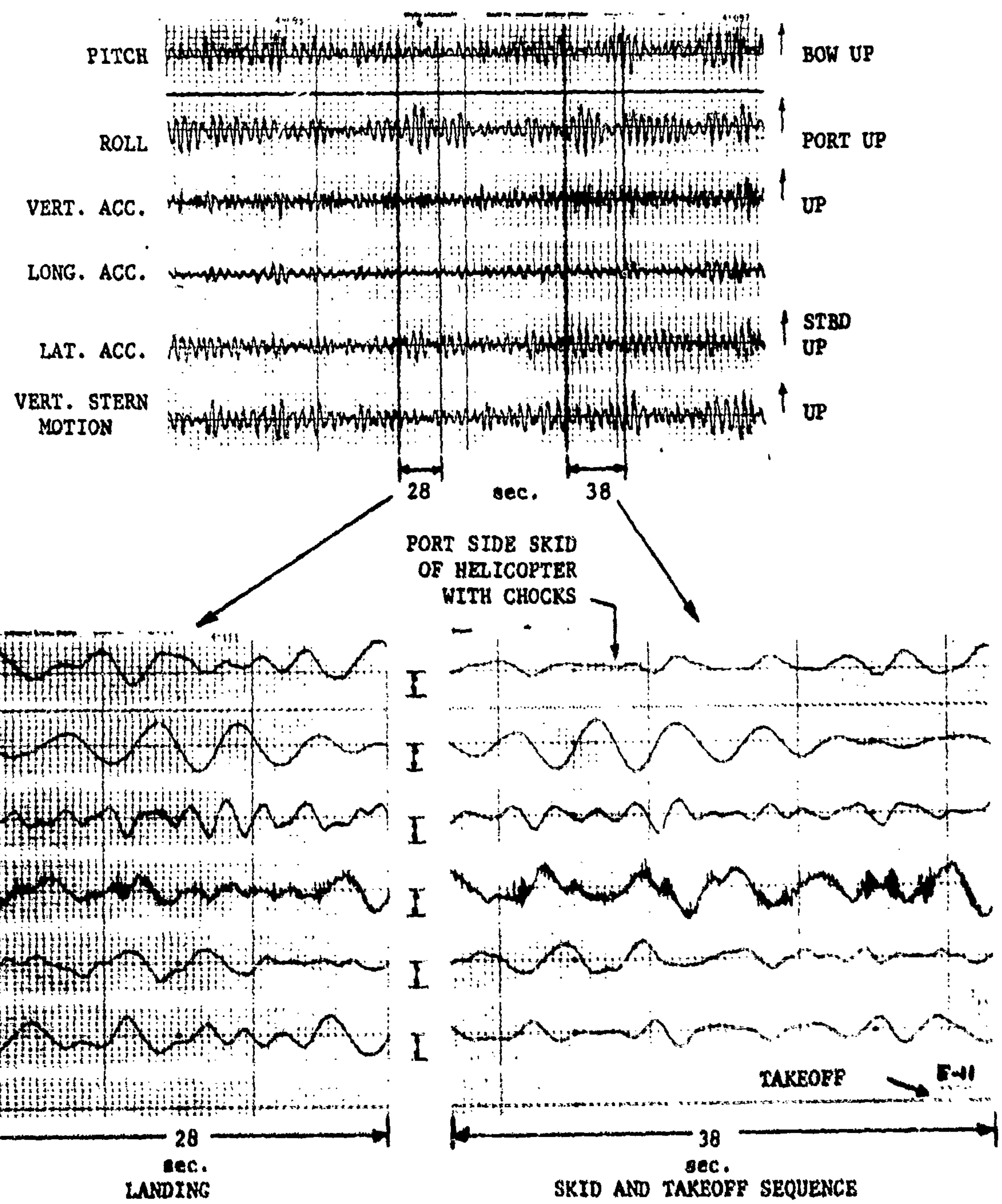
SUCCESSFUL CROSS DECK LANDING - E-11

SUCCESSFUL CROSS DECK TAKEOFF - E-12

WIND SPEED = 23 Knots
DIRECTION
REL. TO SHIP = 285°

SHIP SPEED = 7 Knots
DIRECTION
REL. TO SEA = 093°

Figure 9 – Example of Ship Motion Time Histories during Some Typical and Atypical Aircraft Events, Day 2, Flight 1 (5)



DAY 4

FLIGHT #11

Data	Original (Top Figure) 20 Divisions =	Cross Deck Landing (Left Figure) 20 Divisions =	Cross Deck Takeoff (Right Figure) 20 Divisions =
Pitch	2°	.8°	2°
Roll	10°	10°	10°
Vert. Acc.	.1 g	.04 g	.1 g
Long. Acc.	.03 g	.01 g	.01 g
Lat. Acc.	.1 g	.1 g	.1 g
Vert. Stern Motion	6.36 ft.	2.62 ft.	6.34 ft.

Figure 10 – Ship Motion Time Histories during a Cross Deck Landing, Helicopter Skid and Subsequent Emergency Takeoff, Day 4, Flight 1 (11)

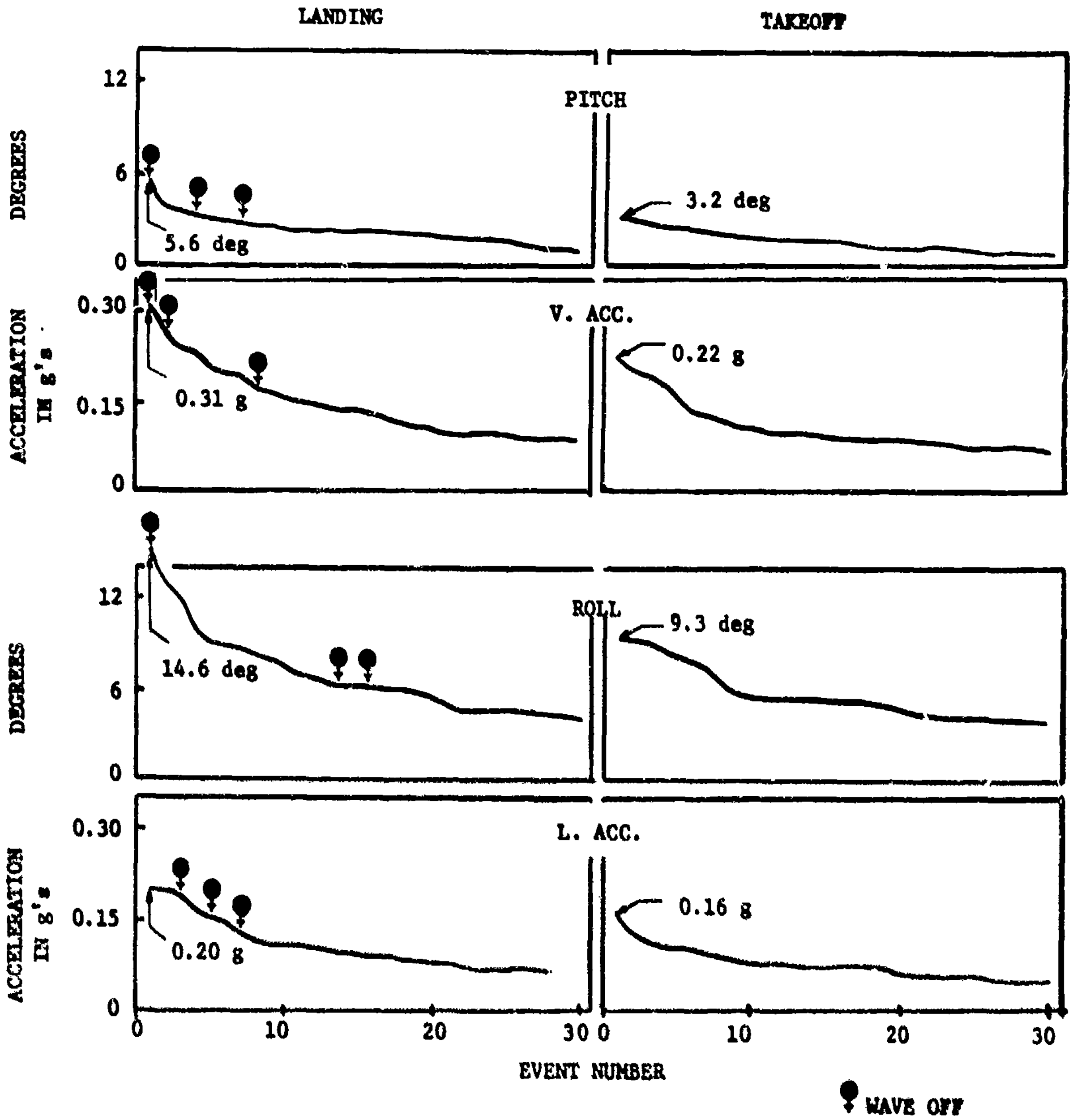
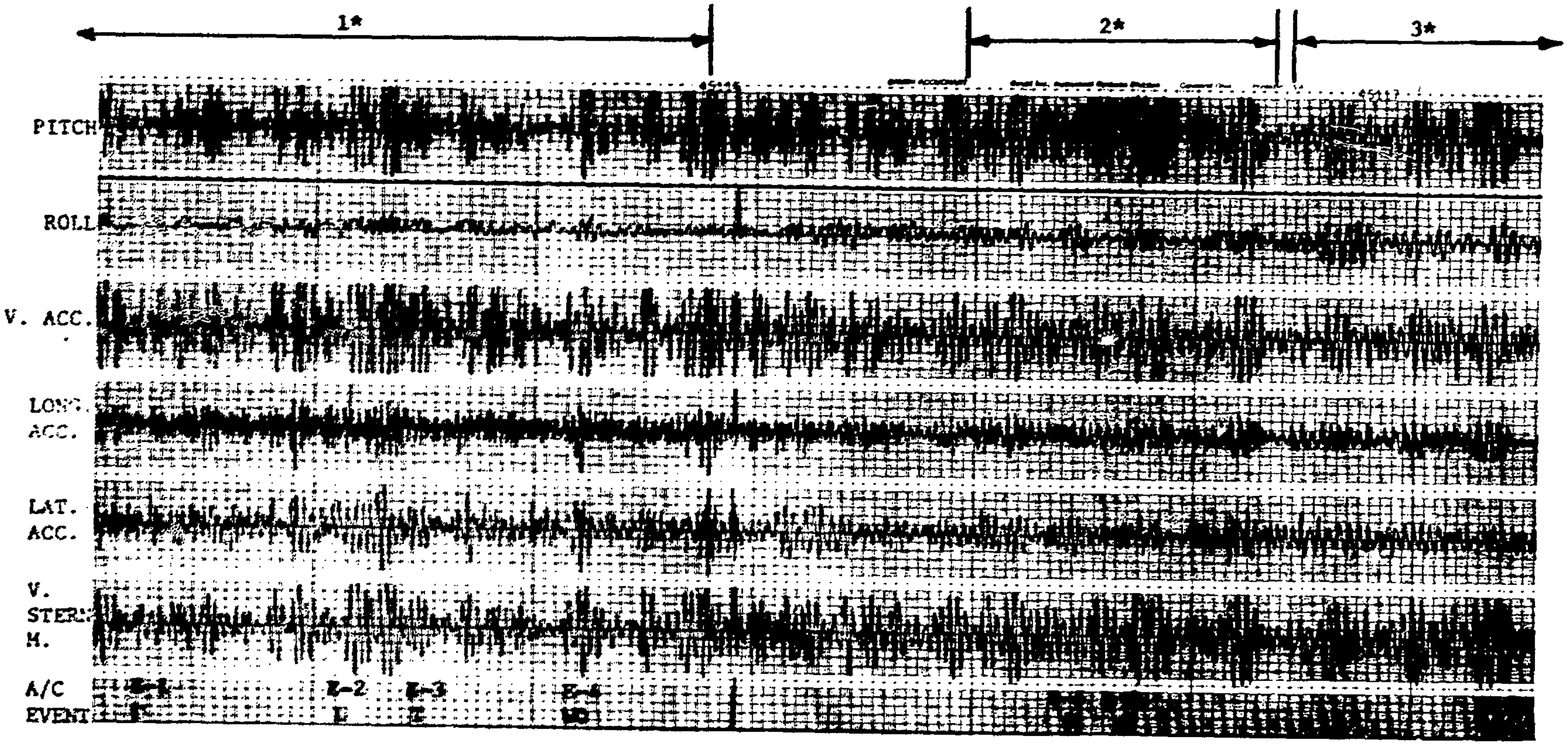


Figure 11 – Summary of Ship Motions during 30 Highest Aircraft Events
(Events ordered by pitch, vertical acceleration, roll, and lateral acceleration)



Data		Direction
PITCH	2° = 20 DIV	Bow up
ROLL	10° = 20 Div	Port up
VERT. ACC.	0.1 g = 20 Div	Up
LONG. ACC.	0.05 g = 20 Div	
LAT. ACC.	0.10 g = 20 Div	Toward Stbd
VERT. STERN MOTION	6.56 Ft = 20 Div	

*Stable Ship Conditions
(See page 4)

Figure 12 – Ship Motion Time Histories during Entire Last Flight of Trial

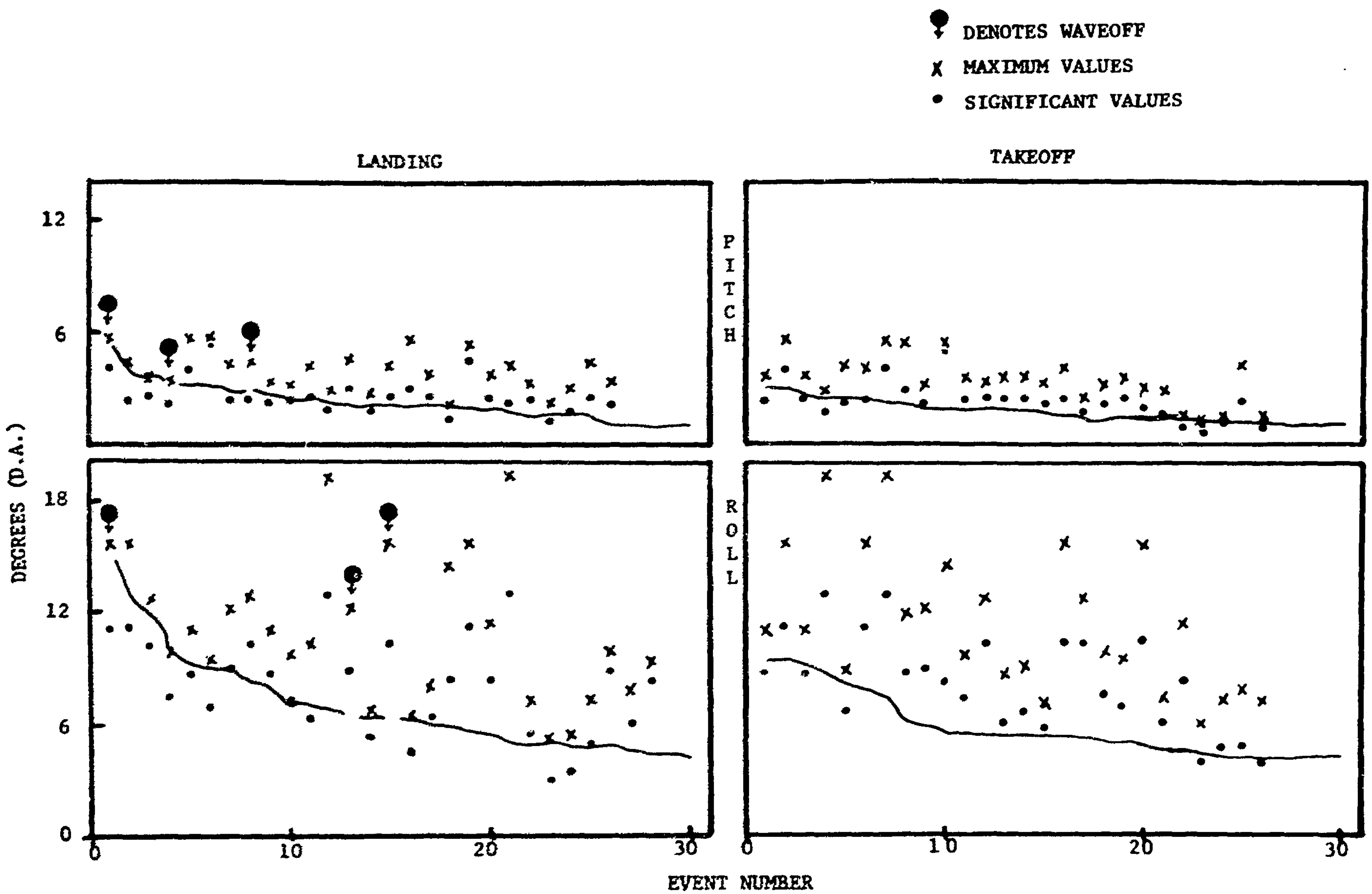


Figure 13 – Summary of Pitch and Roll Motions during Aircraft Events
(Includes the significant and maximum ship motions during stable ship conditions in which the aircraft events occurred)

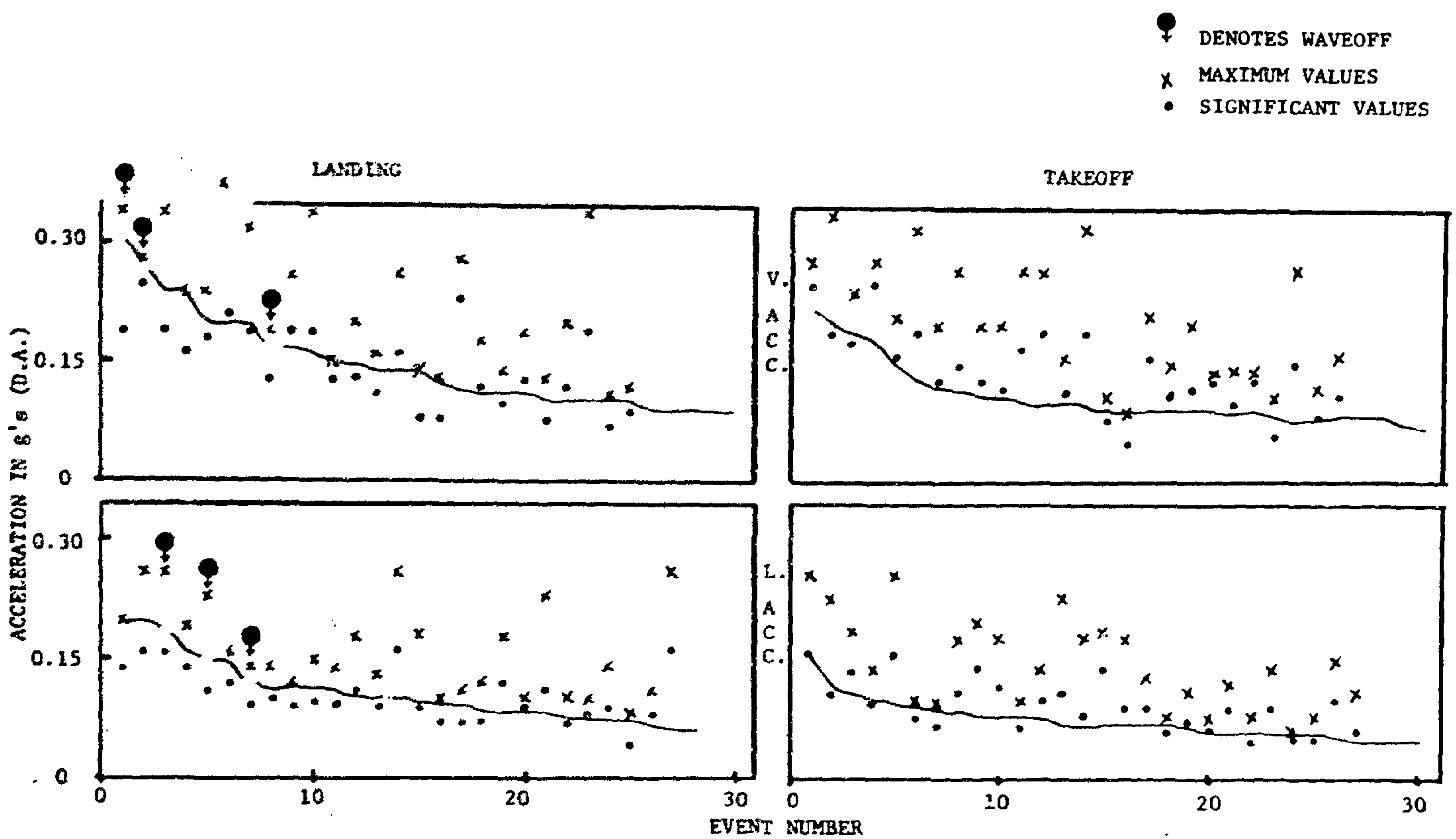
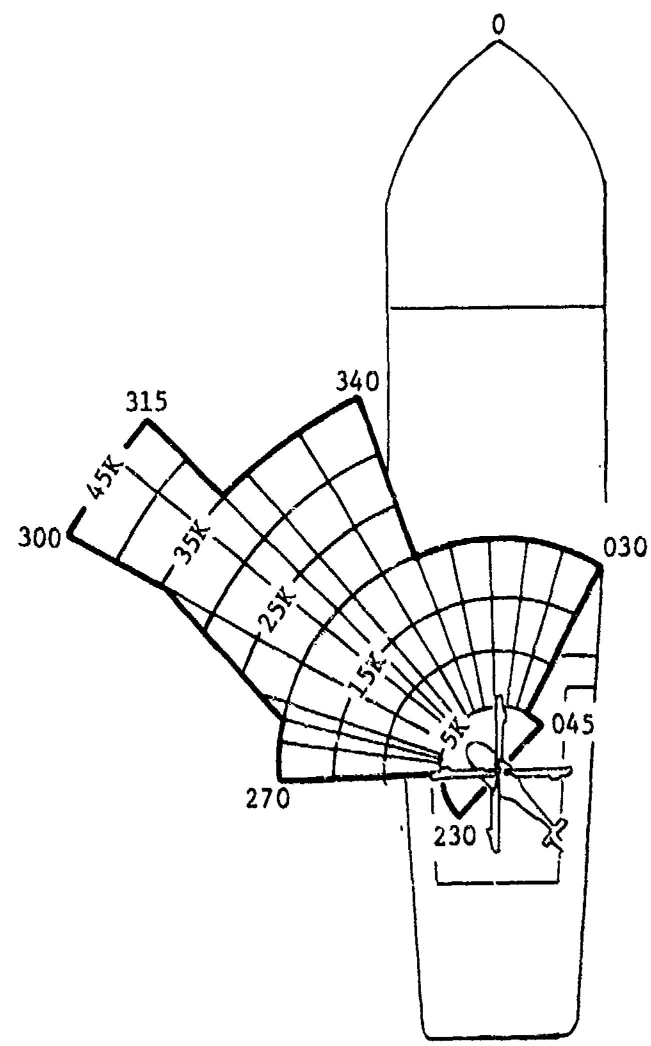


Figure 14 – Summary of Vertical and Lateral Accelerations during Aircraft Events
(Includes the significant and maximum ship motions during stable ship conditions in which the aircraft events occurred)

SH-2F
DLG-26 CLASS SHIPS



NIGHT 0-8 DEGREE SHIP ROLL*
0-1 DEGREE SHIP PITCH*
WHITE LIGHTS ONLY

*INCLINOMETER MEASUREMENT
SEE APPENDIX B

Figure 15 – Example of Wind Limitations and Aircraft Launch and Recovery
(Ship envelope is for operation of the SH-2F helicopter with DLG-26-Class ships)

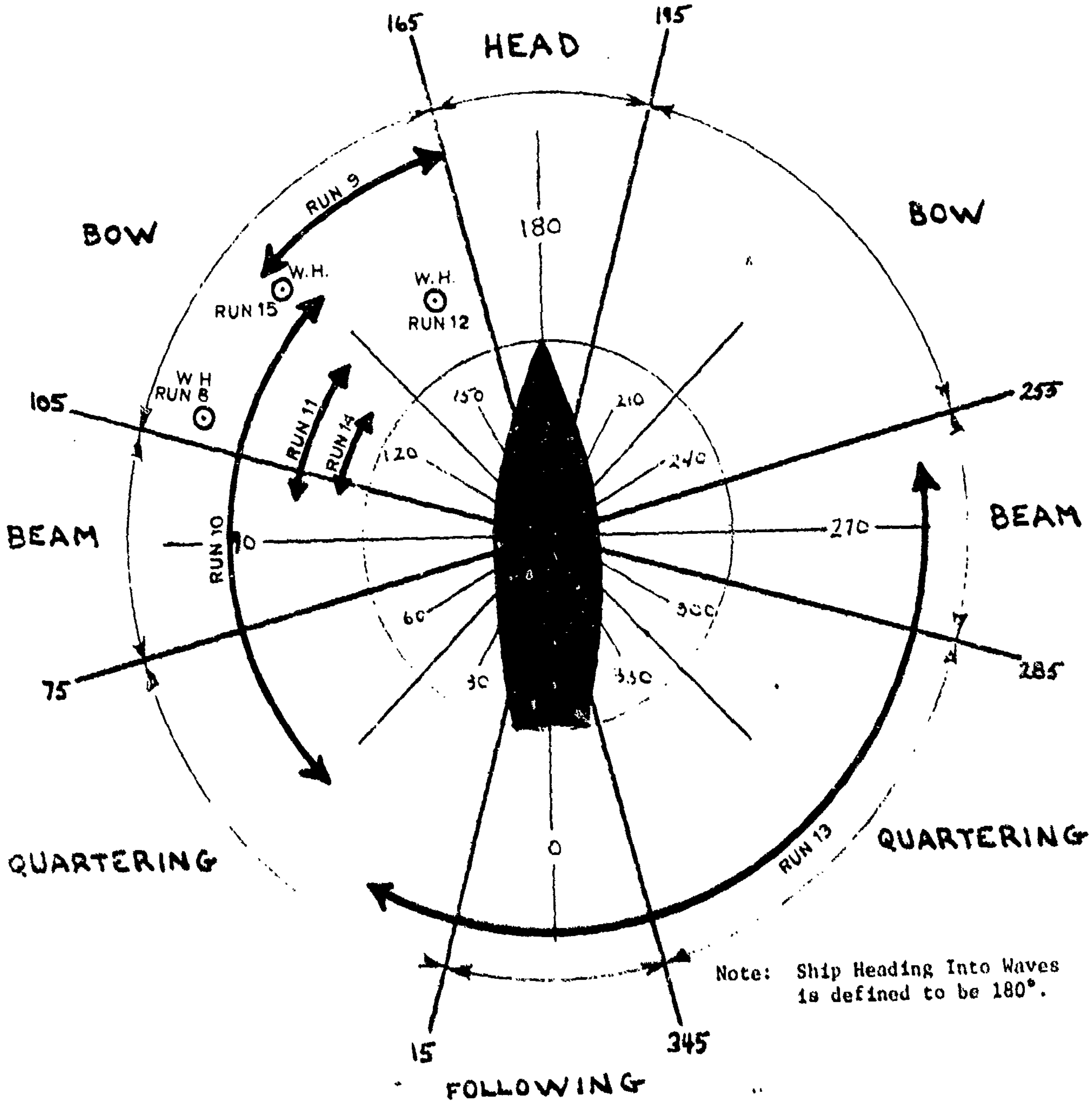


Figure 16 – Maximum Variations in Heading Relative to the Sea within Flights for Trial Day 2

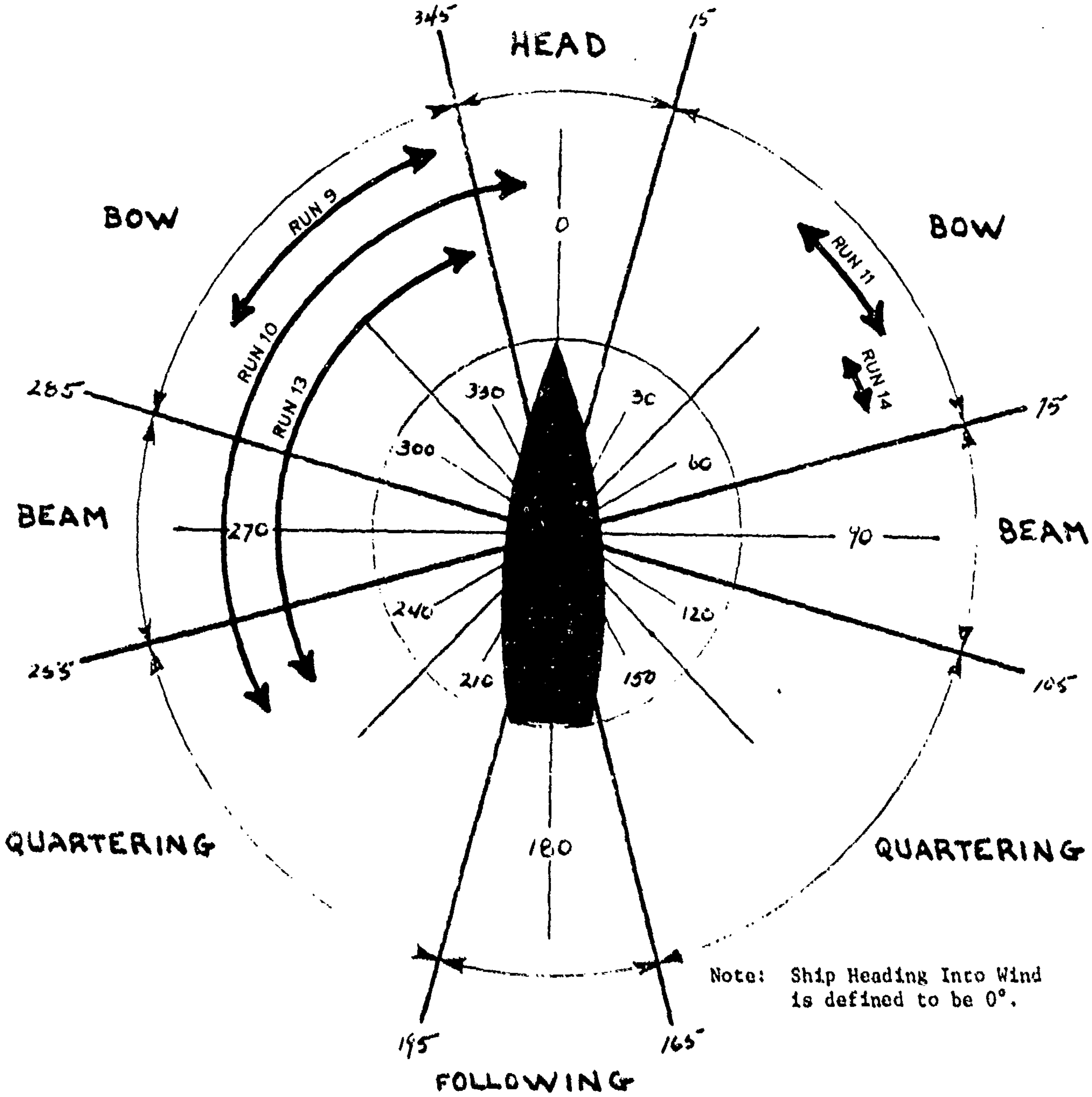
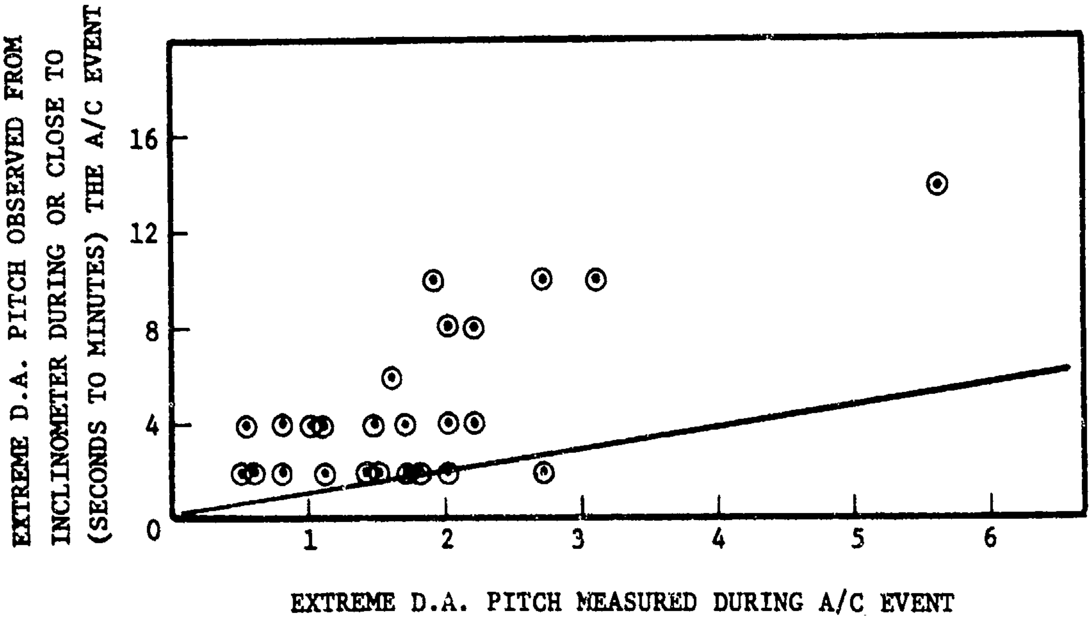


Figure 17 – Maximum Variation in Wind Direction Relative to the Ship within Flights for Trial Day 2



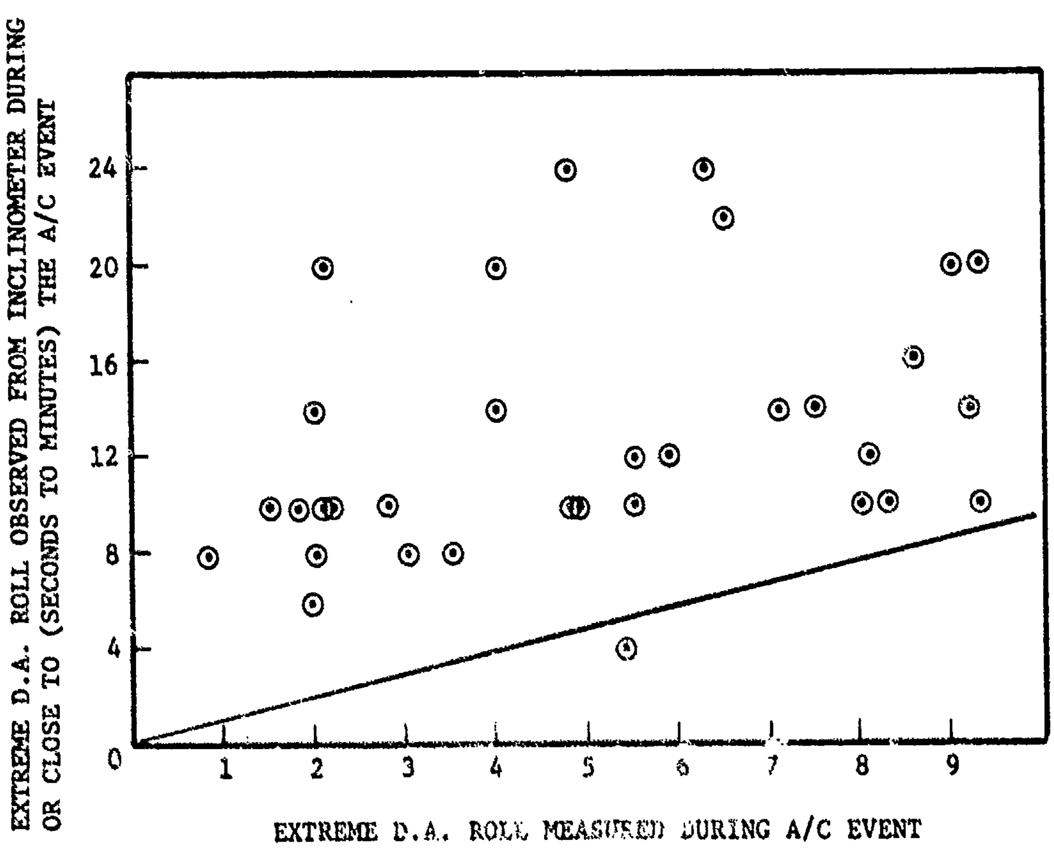


Figure 18 – Comparison of Inclinometer-Based Readouts and NSRDC Electronic Measurements of Extreme Ship Roll and Pitch during Aircraft Event
(Both measurements are given in double amplitudes)

TABLE 4 - SUMMARY OF SIGNIFICANT AND MAXIMUM DOUBLE AMPLITUDES DURING STABLE SHIP CONDITIONS

TRIAL PARTICULARS					SHIP, WIND, & SEA CONDITIONS									SIGNIFICANT & MAXIMUM DOUBLE AMPLITUDE SHIP RESPONSES												
RUN NO.	FLIGHT NO.	DAY	TIME ABSOLUTE	TIME DURATION (SEC)	SHIP SPEED (KTS)	SHIP COURSE (DEG)	RELATIVE COURSE (DEG)	TYPE SEA	TRUE WIND SPEED (KTS)	TRUE WIND DIRECTION (DEG)	SEA STATE	WAVE HEIGHT (FT)		PITCH (DEG)		ROLL (DEG)		VERTICAL ACCELERATION (G'S)		LATERAL ACCELERATION (G'S)		LONGITUDINAL ACCELERATION (G'S)		VERTICAL STERN MOTION (FT)		EVENTS
												SIGN.	MAX.	SIGN.	MAX.	SIGN.	MAX.	SIGN.	MAX.	SIGN.	MAX.	SIGN.	MAX.	SIGN.	MAX.	
2	1	1	1000	1565	8.3	240	153	BOW	13.6	212				.80	1.12	3.83	7.36	.06	.11	.05	.07	.008	.013	3.12	5.14	E-1, E-2
			1042	970	14.5	168	225	BOW	16.3	235				.74	1.15	2.44	3.24	.06	.10	.04	.06	.012	.019	2.42	3.20	E-4, E-5, E-6
			1059	910	9.0	205	188	HEAD	16.0	221				.77	1.58	2.34	3.55	.06	.08	.04	.06	.009	.013	2.81	5.08	E-7 thru E-11
			1118	1955	9.1	228	165	HEAD	14.0	211				.70	1.08	3.38	5.43	.06	.11	.04	.08	.009	.015	2.66	4.41	E-12 thru E-16
			1153	440	9.5	260	125	BOW	13.4	201				.75	.99	3.72	5.06	.07	.10	.05	.07	.009	.011	2.89	3.49	E-17
3	—	1	1344	595	0.0	150	245	BOW	—	—	M3	4.3	7.5	1.02	1.58	2.95	3.99	.10	.14	.06	.11	.010	.018			
4	2	1	1412	755	10.5	276	118	BOW	—	—				.69	.97	3.40	4.90	.05	.07	.03	.05	.007	.011	2.41	2.90	
			1440	745	13.5	303	090	BEAM	14.4	198				.92	1.38	3.02	3.88	.10	.14	.07	.12	.013	.020	3.58	5.87	E-3 thru E-6
			1457	1175	18.9	360	033	QUART.	15.6	216				.73	1.04	4.06	7.20	.08	.13	.06	.09	.010	.012	2.88	5.27	E-7 thru E-10
			1517	535	14.3	005	028	QUART.	13.1	218				.71	.93	4.01	5.96	.06	.08	.05	.08	.007	.012	2.68	3.63	E-11, E-12
			1529	465	27	000	013	FOLLOW.	16.4	226				.76	1.21	3.78	5.17	.05	.08	.04	.05	.008	.012	2.87	4.67	E-13
			1542	545	18.8	310	083	BEAM	15.6	112				.75	1.03	4.41	6.25	.10	.14	.08	.11	.014	.018	3.20	4.12	E-14
			1607	520	25.3	135	258	BEAM	18.6	016				.85	1.15	5.55	7.47	.09	.12	.06	.08	.015	.018	3.19	4.09	E-17, E-18
			1618	240	22.0	095	298	QUART.	19.5	308				.63	.78	4.94	7.90	.06	.09	.04	.05	.013	.014	2.28	2.93	E-19, E-20, E-21
5**	3	1	1923	1250	9.5	282	112	BOW	12.8	265	2-L3**			.63	1.01	3.39	5.11	.04	.07	.04	.06	.009	.014	2.33	3.33	E-1 thru E-4
			1945	470	9.3	278	116	BOW	11.0	297				.56	.78	4.03	5.45	.03	.05	.03	.03	.006	.008	2.00	2.84	E-5
			1954	530	9.2	263	130	BOW	15.9	271				.56	.76	2.72	3.98	.04	.05	.03	.04	.008	.011	2.09	2.80	E-6
			2006	785	19.0	261	132	BOW	11.8	287				.43	.66	2.58	3.55	.04	.06	.03	.05	.008	.012	1.69	2.41	E-7, E-8
			2021	990	22.7	262	131	BOW	4.8	196				.48	.58	2.97	4.04	.05	.07	.03	.04	.009	.011	1.55	2.31	E-9
			2041	880	13.0	304	089	BEAM	3.6	209				.56	.81	2.53	3.72	.06	.08	.04	.05	.008	.010	2.15	2.90	E-10, E-11, E-12
			2057	925	13.6	356	058	QUART.	14.6	205				.48	.60	2.72	4.65	.04	.07	.03	.05	.006	.010	2.03	2.54	E-13, E-14, E-15
6**	4	1	2242	2020	8.4	174	219	BOW	18.0	130				.84	1.58	2.29	3.81	.07	.11	.04	.07	.009	.017	3.10	4.97	E-1 thru E-4
			2318	620	10.8	176	217	BOW	23.8	122				.89	1.30	2.10	2.71	.07	.11	.04	.06	.011	.017	3.12	4.21	E-5, E-6
			2330	530	12.3	190	203	BOW	18.0	173				.65	1.02	2.87	3.11	.05	.07	.04	.06	.007	.011	2.32	3.05	E-7, E-8
			2345	520	9.1	178	215	BOW	17.2	100				1.03	1.55	2.86	4.96	.10	.13	.06	.11	.011	.017	3.80	4.72	E-9, E-10
8	—	2	0340	582	0.0	285	108	BOW	—	—	L5	8.9	13.8	2.30	3.50	8.20	10.90	.14	.21	.12	.17	.016	.025			
9	5	2	0835	840	9.8	258	165	HEAD	24.3	270				2.49	3.63	6.63	8.80	.15	.27	.10	.14	.018	.027	8.16	12.36	E-1, E-2, E-3
			0854	590	17.8	273	150	BOW	18.8	215				2.40	3.72	5.99	7.13	.19	.26	.12	.18	.031	.040	7.66	11.42	E-4, E-5
			0906	560	9.4	291	133	BOW	21.0	209				2.61	3.39	7.45	9.77	.18	.24	.14	.20	.023	.032	8.93	10.92	E-6, E-7
10	5	2	0920	1665	7.0	306	093	BEAM	22.0	219				2.43	4.31	11.12	15.58	.19	.34	.16	.26	.023	.038	9.48	14.63	E-8 thru E-13
			0957	690	7.4	332	067	QUART.	30.6	157				2.18	3.10	10.26	15.71	.16	.21	.14	.19	.021	.030	8.50	12.54	E-14, E-15, E-16
			1012	700	7.0	353	045	QUART.	27.0	219				2.21	4.06	10.23	12.69	.12	.20	.09	.18	.020	.037	8.04	16.01	E-17 thru E-20
			1028	590	19.0	261	137	BOW	18.6	247				1.94	2.86	6.27	10.18	.16	.26	.09	.14	.025	.039	6.36	8.22	E-21, E-22, E-23
11	6	2	1151	640	9.3	198	100	BEAM	13.7	143				2.05	3.05	3.17	4.28	.11	.16	.06	.08	.020	.029	6.05	8.78	E-1, E-2
			1223	940	16.2	178	120	BOW	24.1	087				2.47	4.07	4.57	5.83	.19	.32	.10	.15	.026	.041	7.39	11.78	E-7 thru E10
			1236	690	15.0	167	131	BOW	27.7	075				2.53	4.47	5.13	7.07	.22	.38	.12	.16	.030	.051	8.82	12.04	E-11
12	—	2	1515	1627	0.0	150	152	BOW	—	—	M5	9.3	14.0	2.60	4.30	10.20	17.70	.17	.26	.14	.24	.018	.033			
13**	7	2	1850	663	10.0	268	050	QUART.	24.3	250				1.24	1.60	5.50	7.18	.08	.11	.06	.08	.013	.019	4.63	7.00	E-1, E-2, E-3
			1906	630	5.0	303	355	FOLLOW.	25.4	233				1.26	1.96	7.33	9.73	.09	.12	.07	.11	.012	.019	4.67	5.79	E-4, E-5
			1933	630	16.6	003	295	QUART.	29.2	221				1.12	2.02	5.82	7.11	.09	.13	.07	.09	.015	.022	4.29	6.42	E-8, E-9
			1949	670	27.0	037	261	BEAM	31.3	227				.34	1.02	6.64	9.01	.04	.07	.05	.06	.013	.020	2.63	3.89	E-10, E-11
			2003	982	20.7	323	335	QUART.	30.1	253				1.28	2.08	6.28	8.03	.13	.14	.09	.12	.020	.025	4.85	6.89	E-12, E-13
14**	7	2	2046	535	2.3	195	185	BEAM	24.5	131				1.77	2.62	4.80	7.32	.11	.16	.07	.10	.013	.023	5.65	8.44	E-18, E-19
			2055	740	3.1	173	125	BOW	22.9	096				2.17	3.26	5.21	6.68	.13	.19	.09	.14	.014	.031	6.96	10.05	E-20, E-21, E-22
			2120	460	2.3	184	114	BOW	24.0	119				1.69	2.41	4.77	5.75	.12	.18	.08	.12	.013	.026	5.85	8.20	E-23
15**	—	2	2155	1760	0.0	168	130	BOW	—	—	H4	6.9	12.1	1.90	3.60	8.80	16.40	.12	.18	.09	.17	.015	.027			
16	6	3	0838	835	24.7	014	138	BOW	15.7	040				.84	1.01	7.48	8.35	.04	.06	.05	.07	.013	.015	2.95	3.78	E-6 thru E-11
			0853	650	25.2	043	110	BOW	7.1	304				1.04	1.38	8.29	11.28	.10	.14	.08	.10	.017	.026	4.16	5.12	E-12 thru E-15
			0907	780	25.3	310	203	BOW	20.9	041				1.13	1.63	8.85	12.10	.11	.15	.08	.11	.019	.024	4.56	6.17	E-16 thru E-19
														[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.11	.18	.019	.030	6.78	10.28	E-20, E-21

			0907	780	25.3	316	203	Bow	20.1	041				1.81	2.33	8.31	14.41	.17	.27	.11	.18	.019	.030	6.78	10.28	E-20, E-21
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.012	2.87	4.67	E-13
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	BEAM	[illegible]	172				.75	1.03	1.41	6.25	.10	.14	.08	.11	.014	.018	3.20	4.12	E-14
			1587	820	22.3	135	258	BEAM	18.6	016				.85	1.15	5.55	7.47	.09	.12	.06	.08	.015	.018	3.19	4.09	E-17, E-18
			1618	240	220	015	298	QUART.	19.5	308				.63	.78	4.94	7.90	.06	.09	.04	.05	.013	.014	2.28	2.93	E-19, E-20, E-21
5*	3	1	1923	1250	8.5	282	112	Bow	12.8	265	2-L3**			.63	1.01	3.39	5.11	.04	.07	.04	.06	.009	.014	2.33	3.33	E-1 thru E-4
			1945	470	9.3	278	116	Bow	11.0	297				.56	.78	4.03	5.45	.03	.05	.03	.03	.006	.008	2.00	2.84	E-5
			1954	530	8.2	263	130	Bow	15.9	271				.56	.76	2.72	3.98	.04	.05	.03	.04	.008	.011	2.09	2.80	E-6
			2006	785	19.0	261	132	Bow	11.8	287				.43	.66	2.58	3.55	.04	.06	.03	.05	.008	.012	1.69	2.41	E-7, E-8
			2021	190	12.7	262	131	Bow	4.8	196				.48	.58	2.97	4.04	.05	.07	.03	.04	.009	.011	1.55	2.31	E-9
			2041	880	13.0	304	089	BEAM	6.4	209				.56	.81	2.53	3.72	.06	.08	.04	.05	.008	.010	2.15	2.90	E-10, E-11, E-12
			2057	925	13.6	336	058	QUART.	14.6	205				.48	.60	2.72	4.65	.04	.07	.03	.05	.006	.010	2.03	2.54	E-13, E-14, E-15
6*	4	1	2242	2020	8.4	174	219	Bow	18.0	130				.84	1.58	2.29	3.81	.07	.11	.04	.07	.009	.017	3.10	4.97	E-1 thru E-4
			2318	610	10.8	176	217	Bow	23.8	122				.89	1.30	2.10	2.71	.07	.11	.04	.06	.011	.017	3.12	4.21	E-5, E-6
			2330	530	12.3	190	203	Bow	18.0	173				.65	1.02	2.87	3.11	.05	.07	.04	.06	.007	.011	2.32	3.05	E-7, E-8
			2345	520	9.1	178	215	Bow	17.2	100				1.03	1.55	2.86	4.96	.10	.13	.06	.11	.011	.017	3.80	4.72	E-9, E-10
8	–	2	0740	582	0.0	285	108	Bow	—	—	L5	8.5	13.8	2.30	3.50	8.20	10.90	.14	.21	.12	.17	.016	.025			
9	5	2	0835	840	9.8	258	165	HEAD	24.3	220				2.49	3.63	6.63	8.80	.15	.27	.10	.14	.018	.027	8.16	12.36	E-1, E-2, E-3
			0854	590	17.8	273	150	Bow	18.8	215				2.40	3.72	5.99	7.13	.19	.26	.12	.18	.031	.040	7.66	11.42	E-4, E-5
			0906	560	9.4	291	133	Bow	21.0	209				2.61	3.39	7.45	9.77	.18	.24	.14	.20	.023	.032	8.93	10.92	E-6, E-7
10	5	2	0920	1665	7.0	306	093	BEAM	22.0	219				2.43	4.31	11.12	15.58	.19	.34	.16	.26	.023	.038	9.48	14.63	E-8 thru E-13
			0957	610	7.4	332	067	QUART.	30.6	157				2.18	3.10	10.26	15.71	.16	.21	.14	.19	.021	.030	8.50	12.54	E-14, E-15, E-16
			1012	780	7.0	353	045	QUART.	27.0	219				2.21	4.06	10.23	12.69	.12	.20	.09	.18	.020	.037	8.04	16.01	E-17 thru E-20
			1028	590	19.0	261	137	Bow	18.6	247				1.94	2.86	6.27	10.18	.16	.26	.09	.14	.025	.039	6.36	8.22	E-21, E-22, E-23
11	6	2	1151	640	9.3	198	100	BEAM	13.7	143				2.05	3.05	3.17	4.28	.11	.16	.06	.08	.020	.029	6.05	8.78	E-1, E-2
			1223	740	16.2	178	120	Bow	24.1	087				2.47	4.07	4.57	5.83	.19	.32	.10	.15	.026	.041	7.39	11.78	E-7 thru E10
			1236	690	15.0	167	131	Bow	27.7	075				2.93	4.47	5.13	7.07	.22	.38	.12	.16	.030	.051	8.82	12.04	E-11
12	–	2	1515	1627	0.0	150	152	Bow	—	—	M5	9.3	14.0	2.60	4.30	10.20	17.70	.17	.26	.14	.24	.018	.033			
13*	7	2	1850	663	10.0	268	030	QUART.	24.3	250				1.24	1.60	5.50	7.18	.08	.11	.06	.08	.013	.019	4.63	7.00	E-1, E-2, E-3
			1906	630	5.0	303	355	FOLLOW.	25.4	233				1.26	1.96	7.33	9.73	.09	.12	.07	.11	.012	.019	4.67	5.79	E-4, E-5
			1933	630	16.6	003	295	QUART.	29.2	221				1.12	2.02	5.82	7.11	.09	.13	.07	.09	.015	.022	4.29	6.42	E-8, E-9
			1949	670	27.0	037	261	BEAM	31.3	227				.34	1.02	6.64	9.01	.04	.07	.05	.06	.013	.020	2.63	3.89	E-10, E-11
			2003	982	20.7	323	335	QUART.	30.1	253				1.28	2.08	6.28	8.03	.13	.14	.09	.12	.020	.025	4.85	6.89	E-12, E-13
14*	7	2	2046	535	2.3	195	103	BEAM	24.5	131				1.77	2.62	4.80	7.32	.11	.16	.07	.10	.015	.023	5.65	8.44	E-18, E-19
			2055	740	3.1	173	125	Bow	22.9	096				2.17	3.26	5.21	6.68	.13	.19	.09	.14	.014	.031	6.96	10.05	E-20, E-21, E-22
			2120	460	2.3	184	114	Bow	24.0	119				1.69	2.41	4.77	5.75	.12	.18	.08	.12	.013	.026	5.85	8.20	E-23
15*	–	2	2155	1760	0.0	168	130	Bow	—	—	H4	6.9	12.1	1.90	3.60	8.80	16.40	.12	.18	.09	.17	.015	.027			
16	8	3	0838	835	24.7	014	138	Bow	15.7	040				.84	1.01	7.48	8.35	.04	.06	.05	.07	.013	.015	2.95	3.78	E-6 thru E-11
			0853	650	25.2	043	110	Bow	7.1	304				1.04	1.38	8.29	11.28	.10	.14	.08	.10	.017	.026	4.16	5.12	E-12 thru E-15
			0907	780	25.3	310	203	Bow	20.9	041				1.13	1.63	8.85	12.10	.11	.15	.08	.11	.019	.024	4.56	6.17	E-16 thru E-19
			0926	845	12.5	263	250	Bow	20.0	353				1.81	2.33	8.31	14.41	.17	.27	.11	.18	.019	.030	6.78	10.28	E-20, E-21
			0941	1460	11.6	233	280	BEAM	25.7	023				1.74	2.91	5.97	7.64	.13	.20	.08	.18	.016	.024	5.72	9.68	E-22 thru E-27
17	–	3	1025	476	0.0	294	219	Bow	—	—	H4	6.7	10.2	2.20	4.60	5.30	8.10	.16	.28	.10	.17	.014	.024			
18	9	3	1122	1635	11.0	169	344	QUART.	—	—				1.45	2.32	4.32	6.70	.09	.13	.06	.09	.015	.023	4.32	5.95	E-1
			1153	615	4.5	258	255	BEAM	—	—				1.63	2.36	6.01	8.80	.14	.21	.10	.15	.014	.017	6.32	9.55	E-2
			1206	420	10.1	294	219	Bow	—	—				1.59	2.53	4.78	7.04	.15	.22	.11	.14	.017	.025	5.54	7.91	
			1222	705	25.1	000	153	Bow	—	—				.76	.89	5.12	7.57	.06	.10	.05	.08	.017	.029	2.64	3.71	E-3
			1234	1620	25.1	018	135	Bow	—	—				.82	1.35	4.79	7.93	.06	.10	.04	.07	.015	.020	2.73	3.76	E-4
19*	–	3	1820	469	4.5	035	118	Bow	—	—	L3	4.4	6.2	.70	1.10	4.60	6.80	.05	.07	.03	.04	.006	.009			
20*	10	3	1858	1805	15.1	023	130	Bow	14.4	336				.47	.68	2.50	4.28	.03	.06	.02	.04	.007	.010	1.95	2.85	E-1, E-2, E-3
			1916	873	14.0	046	107	Bow	12.8	332				.59	1.07	3.00	4.46	.04	.06	.03	.04	.006	.010	2.15	3.02	E-4, E-5
			1932	1690	11.9	011	142	Bow	15.4	353				.55	.96	3.09	5.89	.04	.06	.03	.04	.007	.011	2.14	3.13	E-6
			2012	2490	12.5	037	115	Bow	15.9	326				.52	.94	2.66	4.93	.04	.06	.03	.05	.007	.010	2.04	3.36	E-7, E-8, E-9
			2056	475	20.4	058	114	Bow	17.7	322				.59	.78	2.55	2.97	.05	.07	.03	.06	.008	.012	2.15	3.31	E-10, E-11
			2106	495	13.4	335	178	HEAD	—	—				.89	1.59	3.65	7.39	.12	.14	.08	.12	.017	.024	3.58	6.20	
21	–	4	0655	682	0.0	096	081	BEAM	—	—	L5	7.5	11.9	2.20	4.10	11.00	11.10	.12	.20	.10	.20	.018	.035			
23	11	4	0802	843	20.3	238	299	QUART.	25.4	033				2.49	3.70	8.68	11.01	.05	.08	.07	.10	.034	.057	8.15	12.52	E-1 thru E-5
			0820	1300	10.8	234	363	QUART.	23.6	034				2.26	3.21	12.80	19.23	.08	.12	.09	.13	.026	.038	8.09	10.97	E-6 thru E-11
			0855	495	15.1	147	030	QUART.	21.3	003				3.03	5.49	8.66	11.78	.16	.23	.11	.21	.031	.052	9.82	16.78	E-14, E-15
			0906	565	6.0	173	004	FOLLOW.	10.4	083				2.12	3.18	7.25	9.30	.16	.26	.12	.16	.027	.044	8.21	10.48	E-16
24	12	4	0426	775	14.9	080	234	Bow	—	—				2.98	4.86	3.68	5.21	.21	.28	.11	.16	.026	.049	9.48	15.88	E-1
25	13	4	1043	725	26.3	094	225	Bow	13.2	337				4.00	5.63	4.42	6.36	.25	.28	.11	.23	.040	.069	12.14	18.59	E-1 thru E-4
			1160	580	9.0	058	262	BEAM	7.2	296				5.36	5.63	6.85	9.40	.23	.28	.10	.14	.034	.047	16.83	18.59	E-5, E-6
			1165	355	3.0	056	264	BEAM	4.7	338				4.44	5.31	10.18	12.77	.17	.21	.09	.10	.033	.048	14.40	18.45	E-7

* NIGHT RUNS: RELATIVE COURSE ASSUMED FROM DAYTIME SWELL CONDITIONS.
** ESTIMATED SEA CONDITION BASED ON MEASURED SHIP MOTIONS.

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TABLE 5 - SUMMARY OF MAXIMUM DOUBLE AMPLITUDES AND INSTANTANEOUS VALUES OF SHIP MOTION DURING AIRCRAFT EVENTS

TABLE 5a - DAY 1 OF TRIAL

TRIAL PARTICULARS							SHIP, WIND, & SEA CONDITIONS								DOUBLE AMPLITUDE & INSTANTANEOUS SHIP RESPONSES									
RUN NO.	FLIGHT NO.	TIME ABSOLUTE	EVENT NO.	MANEUVER DESCRIPTION	TYPE[1]	PILOT'S RATING	SHIP SPEED (KTS)	RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG)	RELATIVE WIND SPEED (KTS)	RELATIVE WIND DIRECTION (DEG)	TRUE WIND SPEED (KTS)	TRUE WIND DIRECTION (DEG)	SEA STATE	PITCH (DEG) D.A.	PITCH (DEG) INST.	ROLL (DEG) D.A.	ROLL (DEG) INST.	VERTICAL ACCELERATION (G'S) D.A.	VERTICAL ACCELERATION (G'S) INST.	LATERAL ACCELERATION (G'S) D.A.	LATERAL ACCELERATION (G'S) INST.	VERTICAL STERN MOTION (FT) D.A.	VERTICAL STERN MOTION (FT) INST.
2	1	1000	1	STBD L	TOS	1.0	5.3	BW-153	240	18.5	340	13.6	212	M3	.44	.15	1.42	.62	.03	.004	.03	.017	1.37	0
			2	PORT TO	TOS	1.0	5.3	BW-153	240	18.5	340	13.6	212		1.07	-.14	2.41	.58	.08	-.032	.03	-.002	2.95	1.32
		1042	4	STBD TO	TOS	1.0	14.5	BW-225	168	30.0	030	16.3	235		.60	-.25	2.58	-.42	.03	-.033	.03	-.001	1.12	1.68
			5	PORT L	TOS	1.0	14.5	BW-225	168	30.0	030	16.3	235		.42	.02	2.09	-1.0	.03	-.016	.03	-.001	1.71	-.29
			6	STBD TO	TOS	1.0	14.5	BW-225	168	30.0	030	16.3	235		.34	.10	.52	-1.4	.02	-.013	.03	-.005	1.02	.39
		1059	7	PORT L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.60	-.01	1.51	.05	.02	-.018	.02	.003	1.53	.71
			8	STBD TO	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.28	.18	.92	-.54	.04	-.004	.01	-.005	.91	0.
			9	PORT L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.70	.41	1.78	-.76	.04	.006	.05	.010	2.67	-1.01
			10	STBD TO	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.30	.13	1.88	.17	.03	-.017	.04	-.012	.59	.20
			11	STBD L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.75	-.01	1.96	.22	.06	-.014	.03	-.002	1.65	.56
		1118	12	STBD TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.46	.07	1.78	.19	.06	-.012	.03	.006	1.60	.20
			13	PORT L	TOS	1.5	9.1	HD-165	228	22.8	350	14.0	211		.63	.21	4.78	-1.9	.06	-.032	.07	.005	3.09	.67
			14	PORT TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.85	.25	2.40	.75	.03	-.010	.01	-.004	1.95	-.27
			15	PORT L	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.35	.46	1.50	.05	.04	-.003	.05	.004	.85	-.47
			16	STBD TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.33	.49	2.17	-.75	.03	-.019	.03	.009	.67	-.08
		1153	17	PORT L	TOS	1.5	9.5	BW-125	260	20.0	325	13.4	201		.49	.15	2.31	-.80	.05	.010	.05	.032	1.29	.22
4	2	1440	3	STBD L	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198	M3	.81	.10	2.39	.88	.10	.005	.08	.011	2.87	-.19
			4	PORT TO	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198		.44	.28	2.03	.61	.05	-.019	.02	-.008	2.59	.01
			5	STBD L	TOS	1.5	13.5	BM-090	303	17.0	305	14.4	198		.77	.21	1.87	2.00	.08	-.031	.04	-.024	2.65	.11
			6	PORT TO	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198		.71	-.02	2.32	1.89	.04	-.025	.01	-.012	3.10	1.39
		1457	7	STBD L	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.78	.31	1.41	.46	.11	.011	.05	.007	4.13	-.90
			8	PORT TO	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.48	.00	4.08	-2.94	.05	-.007	.02	.024	.64	.17
			9	STBD L	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.47	.36	3.20	.60	.09	.016	.04	.009	1.91	-.14
			10	PORT TO	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.68	.04	2.59	-.01	.04	-.034	.04	-.001	.72	.57
		1517	11	STBD L	TOS	2.0	14.3	QET-028	005	8.0	295	13.1	218		.32	.53	1.19	1.33	.03	-.002	.03	-.014	1.17	-.64
			12	PORT TO	TOS	2.0	14.3	QET-028	005	8.0	295	13.1	218		.66	.30	4.25	1.11	.04	-.003	.05	.019	2.53	.11
		1529	13	STBD L	TOS	2.0	7.7	FW-013	020	10.0	225	16.4	226		.47	.21	3.40	.87	.02	-.007	.03	.005	1.04	.36
		1542	14	PORT TO	TOS	1.5	18.8	BM-083	310	18.0	310	15.6	192		.32	.19	1.69	.61	.08	-.018	.03	.001	1.61	.91
		1607	17	PORT L	TOS	1.0	25.3	BM-258	135						.70	.06	1.83	-1.87	.08	-.028	.04	-.014	2.10	1.13
			18	STBD TO	TOS	1.0	25.3	BM-258	135	23.0	045	18.6	254		.33	.05	3.13	-3.46	.05	.009	.02	.006	.96	-.55
		1616	19	PORT L	TOS	1.0	27.0	QET-298	095	15.0	045	19.5	308		.57	.36	2.49	-1.22	.04	-.008	.03	.000	2.37	-.59
			20	STBD TO	TOS	1.5	27.0	QET-298	095	15.0	045	19.5	308		.26	.22	4.21	-4.15	.03	.002	.06	.024	1.17	-.93
			21	PORT L	TOS	1.0	27.0	QET-298	095	15.0	045	19.5	308		.69	-.21	1.07	-.61	.06	-.017	.03	.001	2.66	.89
5*	3	1923	1	STBD L	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265	2-L3**	.50	.44	3.36	.58	.04	.006	.03	000	2.24	-.43
			2	PORT TO	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.76	.21	3.73	-1.66	.02	.000	.02	.006	2.33	.16
			3	STBD L	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.51	.01	3.18	2.08	.06	-.023	.04	-.008	2.70	.72
			4	PORT TO	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.61	.18	3.15	-1.51	.02	-.006	.02	.003	1.56	.14
		[illegible]	[illegible]	[illegible]	[illegible]	2.0	9.3	BW-116	278	20.0	010	11.0	297		.47	.11	2.80	-1.81	.02	-.001	.03	.003	1.32	-.43

| 1945 | 5 | STBD L | TOS | 2.0 | 9.3 | BW-116 | 278 | 20.0 | 010 | 11.0 | 297 |

		1042	4	STBD TO	TOS	1.0	19.5	BW-225	168	30.0	030	16.3	235		.60	-.25	2.58	-.42	.05	-.032	.03	-.001	1.12	1.60
			5	PORT L	TOS	1.0	19.5	BW-225	168	30.0	030	16.3	236		.42	.02	2.09	-1.0	.03	-.016	.03	-.001	1.71	-.29
			6	STBD TO	TOS	1.0	19.5	BW-225	168	30.0	030	16.3	235		.34	.10	.52	-1.4	.02	-.015	.03	-.006	1.02	.39
		1059	7	PORT L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.60	-.01	1.51	.05	.02	-.018	.02	.003	1.53	.71
			8	STBD TO	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.28	.18	.92	-.54	.04	-.004	.01	-.005	.91	0.
			9	PORT L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.70	.41	1.78	-.76	.04	.006	.05	.010	2.67	-1.01
			10	STBD TO	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.30	.13	1.88	.17	.03	-.017	.04	-.012	.59	.20
			11	STBD L	TOS	1.0	9.0	HD-188	205	24.8	010	16.0	221		.75	-.01	1.96	.22	.06	-.014	.03	-.002	1.65	.56
		1118	12	STBD TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.46	.07	1.78	.19	.06	-.012	.03	.006	1.50	.20
			13	PORT L	TOS	1.5	9.1	HD-165	228	22.8	350	14.0	211		.63	.21	4.78	-1.9	.06	-.032	.07	.005	3.09	.67
			14	PORT TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.85	.25	2.40	.75	.03	-.010	.01	-.004	1.95	-.27
			15	PORT L	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.35	.46	1.50	.05	.04	-.003	.05	.004	.85	-.47
			16	STBD TO	TOS	1.0	9.1	HD-165	228	22.8	350	14.0	211		.33	.49	2.17	-.75	.03	-.019	.03	.009	.67	-.08
		1153	17	PORT L	TOS	1.5	9.5	BW-125	260	20.0	325	13.4	201		.49	.15	2.31	-.80	.05	.010	.05	.032	1.29	.22
4	2	1440	3	STBD L	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198	M3	.81	.10	2.39	.88	.10	.005	.08	.011	2.87	-.19
			4	PORT TO	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198		.44	.28	2.03	.61	.05	-.019	.02	-.008	2.59	.01
			5	STBD L	TOS	1.5	13.5	BM-090	303	17.0	305	14.4	198		.77	.21	1.87	2.00	.08	-.031	.04	-.024	2.65	.11
			6	PORT TO	TOS	2.0	13.5	BM-090	303	17.0	305	14.4	198		.71	-.02	2.32	1.89	.04	-.025	.01	-.012	3.10	1.39
		1457	7	STBD L	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.78	.31	1.41	.46	.11	.011	.05	.007	4.13	-.90
			8	PORT TO	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.48	.00	4.08	-2.94	.03	-.007	.02	.024	.64	.17
			9	STBD L	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.47	.36	3.20	.60	.09	.016	.04	.009	1.91	-.14
			10	PORT TO	TOS	2.0	18.9	QET-033	000	12.0	285	19.6	216		.68	.04	2.59	-.01	.04	-.034	.04	-.001	.72	.57
		1517	11	STBD L	TOS	2.0	14.3	QET-028	005	8.0	295	13.1	218		.32	.53	1.19	1.33	.03	-.002	.03	-.014	1.17	-.64
			12	PORT TO	TOS	2.0	14.3	QET-028	005	8.0	295	13.1	218		.66	.30	4.25	1.11	.04	-.003	.05	.019	2.53	.11
		1529	13	STBD L	TOS	2.0	7.7	FW-013	020	10.0	225	16.4	226		.47	.21	3.40	.87	.02	-.007	.03	.005	1.04	.36
		1542	14	PORT TO	TOS	1.5	18.8	BM-083	310	18.0	310	15.6	192		.52	.19	1.69	.61	.08	-.018	.03	.001	1.61	.91
		1607	17	PORT L	TOS	1.0	25.3	BM-258	135	23.0	045	18.6	254		.70	.06	1.83	-1.87	.08	[illegible]	.04	-.014	2.10	1.13
			18	STBD TO	TOS	1.0	25.3	BM-258	135						.33	.05	3.13	-3.46	.05	[illegible]	.02	.006	.96	-.55
		1618	19	PORT L	TOS	1.0	27.0	QET-298	095	15.0	045	19.5	308		.57	.36	2.49	-1.22	.04	-.008	.03	.000	2.37	-.59
			20	STBD TO	TOS	1.5	27.0	QET-298	095	15.0	045	19.5	308		.26	.22	4.21	-4.15	.03	.002	.05	.024	1.17	-.93
			21	PORT L	TOS	1.0	27.0	QET-298	095	15.0	045	19.5	308		.69	-.21	1.07	-.61	.06	-.017	.03	.001	2.66	.89
6*	3	1923	1	STBD L	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265	2-L3**	.50	.44	3.36	.58	.04	.006	.03	.000	2.24	-.43
			2	PORT TO	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.76	.21	3.73	-1.66	.02	.000	.02	.006	2.33	.16
			3	STBD L	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.51	.01	3.18	2.08	.06	-.023	.04	-.008	2.70	.72
			4	PORT TO	TOS	1.0	9.5	BW-112	282	22.0	350	12.8	265		.61	.18	3.15	-1.51	.02	-.006	.02	.003	1.66	.14
		1945	5	STBD L	TOS	2.0	9.3	BW-116	278	20.0	010	11.0	297		.47	.11	2.80	-1.81	.02	-.001	.03	.003	1.32	-.43
		1954	6	PORT TO	TOS	2.0	9.2	BW-130	263	25.0	005	15.9	271		.34	.35	3.36	-1.20	.03	-.014	.02	.015	1.26	.11
		2006	7	STBD L	TOS	2.5	19.0	BW-132	261	30.0	010	11.8	287		.41	.44	1.39	-.95	.04	-.009	.03	.005	1.61	-.18
			8	PORT TO	TOS	2.0	19.0	BW-132	261	30.0	010	11.8	287		.42	.30	1.31	-.17	.06	.007	.03	.001	1.50	-.50
		2021	9	STBD L	TOS	2.0	22.7	BW-131	262	25.0	350	4.8	196		.23	.26	1.90	1.19	.02	-.001	.01	.012	1.18	.33
		2041	10	PORT TO	TOS	1.5	13.0	BM-089	304	15.0	325	8.6	209		.28	.15	2.98	.59	.03	-.025	.04	-.012	.64	.45
			11	STBD L	TOS	1.0	13.0	BM-089	304	15.0	325	8.6	209		.57	.28	2.12	-.02	.05	.006	.04	.013	2.21	.01
			12	PORT TO	TOS	1.5	13.0	BM-089	304	15.0	325	8.6	209		.45	.01	.66	.42	.03	.003	.01	-.004	1.48	.54
		2057	13	STBD L	TOS	1.5	13.6	QET-058	336	11.7	290	14.6	205		.28	.28	.63	.92	.03	-.005	.03	-.02	.70	-.07
			14	PORT TO	TOS	1.5	13.6	QET-058	336	11.7	290	14.6	205		.22	.24	1.00	.26	.02	.003	.02	.011	1.07	-.19
			15	STBD L	TOS	2.0	13.6	QET-058	336	11.7	290	14.6	205		.250	.20	.78	-.04	.03	-.010	.03	.000	1.41	-.08
6*	4	2242	1	PORT L	TOS	1.5	8.4	BW-219	174	24.8	030	18.0	218	2-L3**	.55	.19	2.09	-1.22	.07	-.013	.05	-.004	2.61	.84
			2	STBD TO	TOS	1.0	8.4	BW-219	174	24.8	030	18.0	218		.57	.12	2.22	-.54	.04	.002	.05	-.015	1.24	-.26
			3	PORT L	TOS	1.5	8.4	BW-219	174	24.8	030	18.0	218		.69	.49	.46	-.68	.07	.016	.02	-.009	2.80	1.45
			4	STBD TO	TOS	1.5	8.4	BW-219	174	24.8	030	18.0	218		.68	.01	1.02	-1.27	.04	.015	.04	-.008	2.17	-.29
		2318	5	PORT L	TOS	1.5	10.8	BW-217	176	28.5	030	23.8	230		.58	.66	1.94	-1.63	.09	-.010	.03	.02	3.47	-.78
			6	STBD TO	TOS	1.5	10.8	BW-217	176	28.5	030	23.8	230		.35	.21	1.39	-1.28	.04	.014	.02	.002	1.18	-.67
		2330	7	PORT L	TOS	2.0	12.3	BW-205	190	30.0	010	18.0	207		.31	.19	.98	.19	.04	-.010	.03	.006	1.28	.71
			8	STBD TO	TOS	2.5	12.3	BW-203	190	30.0	010	18.0	207		.63	.39	2.20	.07	.05	.011	.03	.007	1.95	-.48
		2345	9	PORT L	TOS	2.0	9.1	BW-215	178	21.0	053	17.2	256		.48	.25	.93	-1.84	.05	-.034	.05	.020	2.15	.50
			10	STBD TO	TOS	1.5	9.1	BW-215	178	21.0	053	17.2	256		.99	-.12	3.38	-1.79	.06	.004	.05	.002	3.84	-.51

* NIGHT RUNS RELATIVE COURSE ASSUMED FROM DAYTIME SWELL CONDITIONS.

** ESTIMATED SEA CONDITIONS BASED ON MEASURED SHIP MOTIONS

* FOR DEFINITION OF TERMS, SEE PAGE 64

TABLE 5b - DAY 2 OF TRIAL

TRIAL PARTICULARS							SHIP, WIND, & SEA CONDITIONS								DOUBLE AMPL... SHIP...		
RUN NO.	FLIGHT NO.	TIME ABSOLUTE	EVENT NO.	MANEUVER DESPRIPTION	TYPE	PILOT'S RATING	SHIP SPEED (KTS.)	RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG.)	RELATIVE WIND SPEED (KTS.)	RELATIVE WIND DIRECTION (DEG.)	TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)	SEA STATE	PITCH (DEG.) D.A.	PITCH (DEG.) INST.	ROLL (DEG.) D.A.
9	5	0835	1	PORT TO	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220	L5	1.25	.68	8.16
			2	STBD L	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220		.77	.20	1.18
			3	PORT TO	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220		1.86	.77	2.84
		0854	4	STBD L	TOS	2.0	17.8	BW - 150	273	32.0	330	18.8	215		1.61	.37	3.58
			5	PORT TO	TOS	1.0	17.8	BW - 150	275	32.0	330	18.8	215		3.09	.48	3.53
		0906	6	STBD L	TOS	2.5	9.4	BW - 133	291	24.0	300	21.0	209		3.47	.04	9.84
			7	PORT TO	TOS	1.5	9.4	BW - 133	291	24.0	300	21.0	209		1.79	-.87	4.71
10	5	0920	8	STBD L	TOS	3.0	7.0	BM - 093	306	22.8	285	22.0	213	L5	2.64	.53	6.01
			9	PORT TO	TOS	1.5	7.0	BM - 093	306	22.8	285	22.0	213		2.45	-1.05	7.81
			10	STBD WO	XDK	4.0	7.0	BM - 093	306	22.8	285	22.0	213		2.56	.10	14.64
			11	STBD L	XDK	3.0	7.0	BM - 093	306	22.9	285	22.0	213		1.10	.98	2.56
			12	PORT TO	STD	1.5	7.0	BM - 093	306	22.8	285	22.0	213		1.05	-.57	9.32
			13	STBD L	STD	2.5	7.0	BM - 093	306	22.8	285	22.0	213		3.515	.39	12.78
		0957	14	PORT TO	STD	1.0	7.4	QRT - 067	332	23.3	263	30.6	220		.90	-.04	5.07
			15	STBD L	STD	2.0	7.4	QRT - 067	332	23.3	263	30.6	220		2.28	-.18	6.36
			16	PORT TO	STD	1.0	7.4	QRT - 067	332	23.3	263	30.6	220		.69	1.11	4.41
		1012	17	STBD L	STD	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.76	1.05	2.95
			18	PORT TO	STD	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.89	.00	5.06
			19	STBD L	TOS	3.0	7.0	QRT - 045	353	22.8	240	27.0	219		1.57	.08	12.02
			20	PORT TO	TOS	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.99	.72	5.50
		1028	21	STBD L	STD	1.5	19.0	BW - 137	261	37.3	353	18.6	247		.41	.64	3.97
			22	PORT TO	STD	1.0	19.0	BW - 137	261	37.3	353	18.6	247		.13	.30	.97
			23	STBD L	TOS	1.5	19.0	BW - 137	261	37.3	353	18.6	247		2.03	.25	7.23
11	6	1151	1	PORT L	TOS	1.5	9.3	BM - 100	198	30.0	040	13.7	254	M5	.56	.10	1.96
			2	STBD TO	TOS	1.5	9.3	BM - 100	198	30.0	040	13.7	254		1.15	.62	.82
		1223	7	PORT L	TOS	3.0	16.2	BW - 120	178	28.7	057	24.1	249		2.04	-.03	2.80
			8	STBD TO	TOS	2.5	16.2	BW - 120	178	28.7	057	24.1	269		2.35	0	2.08
			9	PORT L	STD	3.0	16.2	BW - 120	178	28.7	057	24.1	269		1.97	.88	3.51
			10	STBD TO	STD	2.5	16.2	BW - 120	178	28.7	057	24.1	269		1.41	.08	2.48
		1236	11	PORT L	STD	3.0	15.0	BW - 131	167	32.0	060	27.7	279		2.00	.26	4.02
13*	7	1850	1	PORT TO	TOS	1.0	10.0	QRT - 030	268	34.0	343	24.3	250	M5	1.07	.66	3.03
			2	STBD L	TOS	1.5	10.0	QRT - 030	268	34.0	343	24.3	250		.62	.30	4.87
			3	PORT TO	TOS	1.0	10.0	QRT - 030	268	34.0	343	24.3	250		.62	.38	2.87
		1906	4	STBD L	TOS	2.5	5.0	FW - 355	303	27.5	300	26.4	233	H4	1.70	.61	8.03
			5	PORT TO	TOS	1.5	5.0	FW - 355	303	27.5	300	26.4	233		.55	.23	5.61
		1933	8	STBD L	STD	2.5	16.6	QRT - 295	003	19.0	250	29.2	221		.97	-.09	2.81
			9	PORT TO	STD	2.5	16.6	QRT - 295	003	19.0	250	29.2	221		.47	.47	5.32
		1949	10	STBD L	STD	3.0	27.0	BM - 261	037	6.5	240	31.3	227		.51	.06	1.96
			11	PORT TO	STD	2.5	27.0	BM - 261	037	6.5	240	31.3	227		.82	-.19	3.41
		2003	12	STBD L	STD	3.0	20.7	QRT - 335	323	30.0	290	30.1	213		1.14	.91	6.26
			13	PORT TO	STD	1.5	20.7	QRT - 335	323	30.0	290	30.1	213		.81	.01	3.97
14*	7	2046	18	PORT L	ASE OFF	2.0	2.3	BM - 103	195	25.5	060	24.5	259	H4	1.99	.29	4.78
			19	STBD TO	STD	1.5	2.5	BM - 103	195	25.5	060	24.5	259		1.38	.60	4.24
		2055	20	PORT WO	TOS	4.0	3.1	BW - 126	173	23.7	070	22.9	250		3.20	.11	6.47
			21	PORT L	STD	2.5	3.1	BW - 126	173	23.7	070	22.9	250		2.32	.96	4.03
			22	STBD TO	STD	1.5	3.1	BW - 126	173	23.7	070	22.9	250		1.65	.67	1.61
		2120	23	PORT L	STD	2.0	2.3	BW - 114	184	[illegible]	060	24.0	249		.87	.45	2.24

* NIGHT RUNS. RELATIVE COURSE ASSUMED FROM DAYTIME SWELL CONDITIONS.

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TABLE 5b - DAY 2 OF TRIAL

RS			SHIP, WIND, & SEA CONDITIONS								DOUBLE AMPLITUDE & INSTANTANEOUS SHIP RESPONSES									
EUVER RIPTION	TYPE	PILOT'S RATING	SHIP SPEED (KTS.)	RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG.)	RELATIVE WIND SPEED (KTS.)	RELATIVE WIND DIRECTION (DEG.)	TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)	SEA STATE	PITCH (DEG.)		ROLL (DEG.)		VERTICAL ACCELERATION (G'S)		LATERAL ACCELERATION (G'S)		VERTICAL STERN MOTION (FT.)	
											D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.
T TO	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220	L5	1.25	.68	8.16	-.74	.12	.014	.10	.043	5.31	-.56
D L	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220		.77	.20	1.18	.88	.03	.027	.04	.019	2.21	-.90
T TO	TOS	1.0	9.8	HD - 165	258	32.7	333	24.3	220		1.86	.77	2.84	-.30	.08	.011	.04	.028	6.03	-.66
D L	TOS	2.0	17.8	BW - 150	273	32.0	330	18.8	215		1.61	.37	3.58	3.00	.16	.016	.08	.013	5.23	-1.08
T TO	TOS	1.0	17.8	BW - 150	273	32.0	330	18.8	215		3.02	.48	3.53	2.03	.10	-.016	.08	-.035	4.32	-.43
D L	TOS	2.5	9.4	BW - 133	291	24.0	300	21.0	209		3.47	.04	9.84	.55	.20	-.029	.20	-.005	9.60	.69
T TO	TOS	1.5	9.4	BW - 133	291	24.0	300	21.0	209		1.79	-.87	4.71	3.60	.19	-.12	.08	-.001	8.79	5.27
D L	TOS	3.0	7.0	BM - 093	306	22.8	285	22.0	213	L5	2.64	.53	6.01	4.88	.15	.039	.10	-.020	8.73	-2.14
T TO	TOS	1.5	7.0	BM - 093	306	22.8	285	22.0	213		2.45	-1.05	7.81	6.61	.09	-.045	-.10	-.056	6.89	3.02
D WO	XDK	4.0	7.0	BM - 093	306	22.8	285	22.0	213		2.56	.10	14.64	5.66	.31	-.067	.19	-.029	11.77	-.21
D L	XDK	3.0	7.0	BM - 093	306	22.9	285	22.0	213		1.10	.98	2.56	6.29	.09	.028	.06	-.037	3.49	-2.27
RT TO	STD	1.5	7.0	BM - 093	306	22.8	285	22.0	213		1.05	-.57	9.32	7.58	.20	-.076	.16	-.069	8.51	2.67
D L	STD	2.5	7.0	BM - 093	306	22.8	285	22.0	213		3.55	.39	12.78	-.25	.24	-.025	.20	.017	12.25	.14
RT TO	STD	1.0	7.4	QRT - 067	332	23.3	263	30.6	220		.90	-.04	5.07	4.93	.09	.007	.07	-.010	2.23	-.88
D L	STD	2.0	7.4	QRT - 067	332	23.3	263	30.6	220		2.28	-.13	6.36	3.10	.24	-.046	.16	.025	9.91	2.18
RT TO	STD	1.0	7.4	QRT - 067	332	23.3	263	30.6	220		.69	1.11	4.41	3.28	.15	.060	.10	-.005	5.69	3.44
BD L	STD	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.76	1.05	2.93	3.91	.09	.034	.04	-.031	4.82	-3.11
RT TO	STD	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.89	.00	5.06	.75	.11	-.014	.07	.014	6.09	1.74
BD L	TOS	3.0	7.0	QRT - 045	353	22.8	240	27.0	219		1.57	.08	12.02	-2.77	.08	.021	.09	.000	6.67	-.68
RT TO	TOS	2.0	7.0	QRT - 045	353	22.8	240	27.0	219		.99	.72	5.50	3.20	.09	.029	.04	-.018	2.54	-2.20
BD L	STD	1.5	19.0	BW - 137	261	37.3	353	18.6	247		.41	.64	3.97	.18	.06	.021	.06	.019	3.28	-1.45
RT TO	STD	1.0	19.0	BW - 137	261	37.3	353	18.6	247		.13	.30	.97	-.69	.04	.004	.06	-.010	1.82	-.61
BD L	TOS	1.5	19.0	BW - 137	261	37.3	353	18.6	247		2.03	.25	7.23	1.53	.12	.022	.11	-.010	4.88	-3.04
RT L	TOS	1.5	9.3	BM - 100	198	30.0	040	12.7	254	M5	.56	.10	1.96	-2.13	.07	-.020	.04	.005	1.53	-.22
BD TO	TOS	1.5	9.3	BM - 100	198	30.0	040	12.7	254		1.15	.62	.82	-2.43	.08	.031	-.06	.032	6.02	-1.68
RT L	TOS	3.0	16.2	BW - 120	178	28.7	057	24.1	269		2.04	-.03	2.80	-4.13	.20	-.014	.11	.023	6.66	-.13
BD TO	TOS	2.5	16.2	BW - 120	178	28.7	057	24.1	269		2.35	0	2.08	-2.05	.13	-.023	.04	.011	6.28	1.67
RT L	STD	3.0	16.2	BW - 120	178	28.7	057	24.1	269		1.97	.88	3.51	-1.77	.07	.001	.06	.011	5.23	-1.06
BD TO	STD	2.5	16.2	BW - 120	178	28.7	057	24.1	269		1.41	.08	2.48	-3.44	.10	.021	.051	.008	5.36	-.69
RT L	STD	3.0	15.0	BW - 131	167	32.0	060	27.7	279		2.00	.26	4.02	-4.86	.20	-.015	.15	.040	7.18	-.26
RT TO	TOS	1.0	10.0	QRT - 030	268	34.0	343	24.3	250	M5	1.07	.66	3.03	.60	.09	.023	.03	.03	3.10	-1.19
BD L	TOS	1.5	10.0	QRT - 030	268	34.0	343	24.3	250		.62	.30	4.87	.08	.02	.003	.02	.014	2.36	-.12
RT TO	TOS	1.0	10.0	QRT - 030	268	34.0	343	24.3	250		.62	.38	2.87	.74	.04	-.064	.03	-.000	1.94	-.16
BD L	TOS	2.5	5.0	FW - 355	303	27.5	300	26.4	233	H4	1.70	.61	8.03	5.26	.09	-.023	.09	-.026	5.66	-.33
RT TO	TOS	1.5	5.0	FW - 355	303	27.5	300	26.4	233		.55	.23	5.61	-.90	.06	-.014	.06	-.007	2.03	-.52
BD L	STD	2.5	16.6	QRT - 295	003	19.0	250	29.2	221		.97	-.09	2.81	-.08	.04	-.010	.06	.032	2.73	.49
RT TO	STD	2.5	16.6	QRT - 295	003	19.0	250	29.2	221		.47	.47	5.32	3.05	.04	-.007	.06	-.026	2.33	-.83
BD L	STD	3.0	27.0	BM - 261	037	6.5	240	31.3	227		.51	.06	1.96	.97	.04	-.001	.02	-.004	2.00	-.15
RT TO	STD	2.5	27.0	BM - 261	037	6.5	240	31.3	227		.82	-.19	3.41	2.70	.04	.004	.05	-.000	1.13	.12
BD L	STD	3.0	20.7	QRT - 335	323	30.0	290	30.1	213		1.14	.91	6.26	2.64	.14	-.03	.11	-.010	3.34	-.46
RT TO	STD	1.5	20.7	QRT - 335	323	30.0	290	30.1	213		.81	.01	3.97	1.53	.09	-.016	.06	.005	3.36	.55
RT L	ASE OFF	2.0	2.3	BM - 103	195	25.5	060	24.3	259	H4	1.99	.29	4.78	1.05	.15	.011	.04	-.013	7.27	-1.60
BD TO	STD	1.5	2.3	BM - 103	195	25.5	060	24.5	259		1.38	.60	4.24	-5.22	.10	.031	.02	.012	4.45	-.91
RT WO	TOS	4.0	3.1	BW - 125	175	23.7	070	22.9	250		3.20	.11	6.47	-3.33	.17	-.060	.12	.051	9.29	1.91
RT L	STD	2.5	3.1	BW - 125	175	23.7	070	22.9	250		2.32	.96	4.03	.66	.10	-.002	.07	.014	6.55	-1.64
BD TO	STD	1.5	3.1	BW - 125	175	23.7	070	22.9	250		1.63	.67	1.61	-.59	.05	.016	.02	.000	4.13	-1.06
RT L	STD	2.0	2.3	BW - 114	184	26.0	060	24.0	249		.87	.45	2.24	-.40	.10	-.005	.06	-.001	2.69	-.17

UMED FROM DAYTIME SWELL CONDITIONS.

TABLE 5c - DAY 3 OF TRIAL

TRIAL PARTICULARS							SHIP, WIND, & SEA CONDITIONS						
RUN NO.	FLIGHT NO.	TIME ABSOLUTE	EVENT NO.	MANEUVER DESCRIPTION	TYPE	PILOT'S RATING	SHIP SPEED (KTS.)	RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG.)	RELATIVE WIND SPEED (KTS.)	RELATIVE WIND DIRECTION (DEG.)	TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)
16	8	0838	6	PORT L	TOS	1.0	24.7	BW - 138	014	39.4	010	15.7	040
			7	STBD TO	TOS	1.5	24.7	BW - 138	014	39.4	010	15.7	040
			8	PORT L	STD	1.0	24.7	BW - 138	014	39.4	010	15.7	040
			9	STBD TO	STD	1.0	24.7	BW - 138	014	39.4	010	15.7	040
			10	STBD L	TOS	1.5	24.7	BW - 138	014	39.4	010	15.7	040
			11	STBD TO	TOS	1.0	24.7	BW - 138	014	39.4	010	15.7	040
		0853	12	PORT L	TOS	1.0	25.2	BW - 110	043	38.5	344	15.9	001
			13	STBD TO	TOS	2.0	25.2	BW - 110	043	38.5	344	15.9	001
			14	STBD L	TOS	1.5	25.2	BW - 110	043	38.5	344	15.9	001
			15	PORT TO	TOS	1.0	25.2	BW - 110	043	38.5	344	15.9	001
		0907	16	PORT L	ASE OFF	1.5	25.3	BW - 203	310	32.5	040	20.9	041
			17	STBD TO	STD	1.5	25.3	BW - 203	310	32.5	040	20.9	041
			18	PORT L	BOOST OFF	2.0	25.3	BW - 203	310	32.5	040	20.9	041
			19	STBD TO	STD	1.0	25.3	BW - 203	310	32.5	040	20.9	041
		0926	20	PORT L	STD	1.0	12.5	BW - 250	263	20.0	090	20.0	353
			21	STBD TO	STD	2.0	12.5	BW - 250	263	20.0	090	20.0	353
		0941	22	PORT L	STD	2.5	11.6	BM - 280	233	16.7	130	[illegible]	023
			23	STBD TO	STD	1.5	11.6	BM - 280	233	16.7	130	25.7	023
			24	PORT L	STD	1.5	11.6	BM - 280	233	14.7	130	25.7	023
			25	STBD TO	STD	1.5	11.6	BM - 280	233	16.7	130	25.7	023
			26	PORT L	STD	1.5	11.6	BM - 280	233	16.7	130	25.7	023
			27	STBD TO	STD	1.0	11.6	BM - 280	233	14.7	130	25.7	023
18	9		1	—	—	—	11.0	QRT - 344	169	—	—	—	—
			2	—	—	—	4.5	BM - 255	258	—	—	—	—
			3	—	—	—	25.1	BW - 153	000	—	—	—	—
			4	—	—	—	25.1	BW - 135	018	—	—	—	—
20*	10	1858	1	PORT TO	STD	1.0	15.1	BW - 130	023	27.0	337	14.4	336
			2	STBD L	STD	1.0	15.1	BW - 130	023	27.0	337	14.4	336
			3	PORT TO	STD	1.0	15.1	BW - 130	023	27.0	337	14.4	336
		1916	4	STBD L	STD	1.5	14.0	BW - 107	046	21.5	325	12.8	332
			5	PORT TO	STD	1.0	14.0	BW - 107	046	21.5	325	12.8	332
		1932	6	STBD L	TOS	1.0	11.9	BW - 142	011	27.0	350	15.4	353
		2012	7	PORT TO	TOS	1.0	12.5	BW - 115	037	23.3	320	15.9	326
			8	STBD L	STD	1.5	12.5	BW - 115	037	23.3	320	15.9	326
			9	PORT TO	STD	1.0	12.5	BW - 115	037	23.3	320	15.9	326
		2056	10	STBD L	STD	1.5	20.4	BW - 114	038	30.0	325	17.7	322
			11	PORT TO	STD	1.0	20.4	BW - 114	038	30.0	325	17.7	322

*NIGHT RUN: RELATIVE COURSE ASSUMED FROM DAYTIME SWELL CONDITIONS.

5c - DAY 3 OF TRIAL

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IP, WIND, & SEA CONDITIONS							DOUBLE AMPLITUDE & INSTANTANEOUS SHIP RESPONSES									
RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG)	RELATIVE WIND SPEED (KTS.)	RELATIVE WIND DIRECTION (DEG.)	TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)	SEA STATE	PITCH (DEG.)		ROLL (DEG.)		VERTICAL ACCELERATION (G's)		LATERAL ACCELERATION (G's)		VERTICAL STERN MOTION (FT.)	
							D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.
BW - 138	014	39.4	010	15.7	040	H4	.47	.04	2.47	-.77	.04	.014	.03	.000	.83	.43
BW - 138	014	39.4	010	15.7	040		.38	.38	.67	-.16	.03	.004	.02	.009	1.48	-.35
BW - 138	014	39.4	010	15.7	040		.40	.21	3.22	-1.12	.03	.003	.05	.024	1.66	-.05
BW - 138	014	39.4	010	15.7	040		.32	.35	1.65	.48	.03	-.002	.03	-.005	1.84	-1.51
BW - 138	014	39.4	010	15.7	040		.22	.04	2.75	.61	.03	-.010	.03	-.010	.74	-.66
BW - 138	014	39.4	010	15.7	040		.52	.32	1.41	-1.98	.03	.007	.02	.030	1.67	-1.36
BW - 110	043	38.5	344	15.9	001		.45	.71	4.28	.51	.07	-.001	.04	.009	4.58	-.89
BW - 110	043	38.5	344	15.9	001		.33	.33	4.32	1.26	.04	.039	.03	-.004	2.35	-1.52
BW - 110	043	38.5	344	15.9	001		.52	.29	5.69	-.08	.07	-.022	.07	-.009	1.21	1.17
BW - 110	043	38.5	344	15.9	001		.91	.31	2.67	-.58	.06	.06	.10	.024	3.85	-2.67
BW - 203	310	32.5	040	20.9	041		.44	.05	8.94	-2.84	.05	.028	.07	-.007	3.40	-1.85
BW - 203	310	32.5	040	20.9	041		1.08	.65	5.91	-3.47	.09	-.026	.05	-.014	3.89	-2.7
BW - 203	310	32.5	040	20.9	041		[illegible]	.03	2.55	-1.55	.03	-.008	.03	-.020	1.31	-.44
BW - 203	31C	32.5	040	20.9	041		.37	-.15	1.70	-1.43	.06	-.066	.05	.014	2.54	.10
BW - 250	263	20.0	090	20.0	353		.51	-.06	6.08	-3.21	.06	-.037	.10	.003	1.11	1.51
BW - 250	263	20.0	090	20.0	353		.90	.42	5.60	1.63	.11	-.059	.09	.018	3.10	1.38
BM - 280	233	16.7	130	25.7	023		.90	-.11	3.90	-1.05	.08	.025	.06	-.019	3.99	-.90
BM - 280	233	16.7	130	26.7	023		1.15	.06	3.50	-.50	.08	-.013	.03	-.013	2.95	-.19
BM - 280	233	16.7	130	25.7	023		.42	.13	4.39	1.55	.05	-.010	.04	-.000	1.02	.79
BM - 280	233	16.7	130	25.7	023		2.49	.97	5.44	-3.95	.13	.046	.07	.038	7.36	-2.18
BM - 280	233	16.7	130	25.7	023		1.10	.16	3.12	-2.82	.14	-.017	.06	-.007	6.05	-.91
BM - 280	233	16.7	130	25.7	023		.57	.24	4.37	-1.26	.11	.009	.04	.015	3.97	-.60
RT - 344	169	—	—	—	—	H4	—	—	—	—	—	—	—	—	—	—
BM - 255	258	—	—	—	—		—	—	—	—	—	—	—	—	—	—
BW - 153	000	—	—	—	—		—	—	—	—	—	—	—	—	—	—
BW - 135	018	—	—	—	—		—	—	—	—	—	—	—	—	—	—
BW - 130	023	27.0	337	14.4	336	L3	.25	.16	2.81	-.70	.02	-.010	.024	.004	.79	.44
BW - 130	023	27.0	337	14.4	336		.31	.14	1.30	.11	.02	.002	.02	.016	1.11	.18
BW - 130	023	27.0	337	14.4	336		.45	.05	1.76	1.75	.02	.001	.02	.006	.58	.41
BW - 107	046	21.5	325	12.8	332		.58	.26	4.83	2.13	.05	.008	.04	-.012	2.64	.15
BW - 107	046	21.5	325	12.8	332		.49	.077	1.93	.62	.05	.001	.03	.014	1.87	-.25
BW - 142	011	27.0	350	15.4	353		.41	.46	.89	.47	.02	.012	.02	-.006	1.49	-.52
BW - 115	037	23.3	320	15.9	326		.29	.32	.40	1.64	.02	.001	.02	.003	1.46	.09
BW - 115	037	23.3	320	15.9	326		.53	.44	2.42	1.18	.05	.006	.05	-.000	2.54	-.23
BW - 115	037	23.3	320	15.9	326		.24	.23	1.07	1.60	.03	.005	.03	.000	.21	-.16
BW - 114	038	30.0	325	17.7	322		.34	.10	1.14	1.09	.04	.003	.02	-.005	.92	.22
BW - 114	038	30.0	325	17.7	322		.33	.04	3.05	1.09	.04	.004	.02	.003	1.75	.17

NDITIONS.

TABLE 5d -

TRIAL PARTICULARS							SHIP, W	
RUN NO.	FLIGHT NO.	TIME ABSOLUTE	EVENT NO.	MANEUVER DESCRIPTION	TYPE	PILOT'S RATING	SHIP SPEED (KTS.)	RELATIVE SHIP HEADING
23	11	0802	1	STBD TO	TOS	1.5	20.3	QRT-299
			2	PORT L	STD	1.5	20.3	QRT-299
			3	STBD TO	TOS	1.5	20.3	QRT-299
			4	PORT L	XDK	2.0	20.3	QRT-299
			5	STBD TO	XDK	1.5	20.3	QRT-299
		0820	6	PORT L	STD	2.0	10.8	QRT-303
			7	STBD TO	STD	2.0	10.8	QRT-303
			8	PORT L	TOS	2.5	10.8	QRT-303
			9	STBD TO	TOS	2.5	10.8	QRT-303
			10	PORT L	XDK	3.5	10.8	QRT-303
			11	TO	XDK	4.0	10.8	QRT-303
		0855	14	STBD L	TOS	2.0	15.7	QRT-030
			15	PORT TO	TOS	2.0	15.7	QRT-030
		0906	16	STBD L	STD	1.5	6.0	FW-004
24	12		1	—	—	—	19.9	BW-239
25	13	1043	1	PORT TO	STD	1.0	26.3	BW-225
			2	STBD L	ASE OFF	1.5	26.3	BW-225
			3	PORT TO	STD		26.3	BW-225
			4	STBD WO	BOOST OFF	4.0	26.3	BW-225
		1100	5	STBD L	ASE OFF	1.0	9.0	BM-262
			6	PORT TO	TOS		9.0	BM-262
		1105	7	STBD L	BOOST OFF	2.0	3.0	BM-264

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E 5d - DAY 4 OF TRIAL

SHIP, WIND, & SEA CONDITIONS								DOUBLE AMPLITUD… SHIP…			
…IP …EED (…TS.)	RELATIVE SHIP HEADING	TRUE SHIP HEADING (DEG.)	RELATIVE WIND SPEED (KTS.)	RELATIVE WIND DIRECTION (DEG.)	TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)	SEA STATE	PITCH (DEG.) D.A.	PITCH (DEG.) INST.	ROLL (DEG.) D.A.	ROLL (DEG.) INST.
0.3	QRT-299	238	11.0	105	25.4	033	L5	1.71	-.74	9.32	-1.11
20.3	QRT-299	238	11.0	105	25.4	033		1.76	-.59	9.32	-3.27
20.3	QRT-299	238	11.0	105	25.4	033		1.67	-.40	1.45	-.23
20.3	QRT-299	238	11.0	105	25.4	033		0.75	.24	8.12	2.12
20.3	QRT-299	238	11.0	105	25.4	033		2.67	1.41	9.15	-1.78
0.8	QRT-303	234	14.0	135	23.6	034		1.46	-.46	5.54	2.18
0.8	QRT-303	234	14.0	135	23.6	034		2.04	-.57	7.45	-1.77
0.8	QRT-303	234	14.0	135	23.6	034		0.50	.06	7.14	3.09
0.8	QRT-303	234	14.0	135	23.6	034		1.35	1.03	8.55	2.18
.8	QRT-303	234	14.0	135	23.6	034		—	—	—	—
0.8	QRT-303	234	14.0	135	23.6	034		0.54	-.47	1.00	1.00
5.7	QRT-030	147	11.0	255	21.3	003		1.90	.06	4.75	2.87
5.7	QRT-030	147	11.0	255	21.3	003		2.18	-.36	5.95	5.03
.0	FW-004	173	12.0	280	12.4	065		0.99	1.03	2.03	1.71
9.9	BW-239	080	—	—	—	—	L5	—	—	—	—
6.3	BW-225	094	23.5	330	13.2	337	L5	2.21	.20	1.76	.56
6.3	BW-225	094	23.5	330	13.2	337		3.13	.77	2.13	.86
6.3	BW-225	094	23.5	330	13.2	337		2.96	.51	2.94	3.57
6.3	BW-225	094	23.5	330	13.2	337		5.63	-1.22	6.35	4.19
.0	BM-262	058	15.0	310	7.2	296		2.66	1.58	9.02	.81
.0	BM-262	058	15.0	310	7.2	296		2.01	-.19	4.60	-1.54
.0	BM-264	056	13.0	310	4.7	338		1.62	.12	8.31	3.08

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OF TRIAL

ONDITIONS			DOUBLE AMPLITUDE & INSTANTANEOUS SHIP RESPONSES									
TRUE WIND SPEED (KTS.)	TRUE WIND DIRECTION (DEG.)	SEA STATE	PITCH (DEG.)		ROLL (DEG.)		VERTICAL ACCELERATION (G's)		LATERAL ACCELERATION (G's)		VERTICAL STERN MOTION (FT.)	
			D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.	D.A.	INST.
25.4	033	L5	1.71	-.74	9.32	-1.11	.03	-.006	.08	.004	7.18	3.74
25.4	033		1.76	-.59	9.32	-3.27	.04	.026	.07	.003	5.97	0.26
25.4	033		1.67	-.40	1.45	- .23	.03	-.006	.03	-.005	5.65	0.64
25.4	033		0.75	.24	8.12	2.12	.04	000	.06	-.015	4.37	-.36
25.4	033		2.67	1.41	9.15	-1.78	.05	.020	.09	-.007	11.38	-6.13
23.6	034		1.46	-.46	5.54	2.18	.01	-.022	.04	-.001	5.60	2.62
23.6	034		2.04	-.57	7.45	-1.77	.08	.012	.07	.022	5.30	1.23
23.6	034		0.50	.06	7.14	3.09	.05	-.033	.05	-.003	2.04	0.49
23.6	034		1.35	1.03	8.55	2.18	.05	.029	.05	.019	4.78	-2.20
23.6	034		—	—	—	—	—	—	—	—	—	—
23.6	034		0.54	-.47	1.00	1.00	.03	-.029	.03	.025	3.96	3.03
21.3	003		1.90	.06	4.75	2.87	.07	.018	.06	-.022	4.39	-1.78
21.3	002		2.18	-.36	5.95	5.03	.09	-.006	.06	-.029	7.81	.91
12.4	065		0.99	1.03	2.03	1.71	.07	-.017	.09	-.023	3.98	-1.66
—	—	L5	—	—	—	—	—	—	—	—	—	—
13.2	337	L5	2.21	.20	1.76	.56	.18	-.018	.07	-.036	7.71	1.54
13.2.	337		3.13	.77	2.13	.86	.03	.083	.08	.035	7.07	-5.17
13.2	337		2.96	.51	2.94	3.57	.22	-.086	.12	-.004	9.67	3.35
13.2	337		5.63	-1.22	6.35	4.19	.27	.015	.15	-.077	16.59	1.60
7.2	296		2.66	1.58	9.02	.81	.11	.071	.11	-.002	9.42	-5.39
7.2	296		2.01	-.19	4.60	-1.54	.06	-.011	.07	.033	3.27	1.70
4.7	338		1.62	.12	8.31	3.08	.08	-.041	.08	-.032	5.17	1.43

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6A BOWEN PITCH-VERTICAL LANDING

VL Run No.	Event No.	No. Cycles[1]	Time Sec.	Type of Event	Pilot Rating PRS	Steady State Pitch, deg		Aircraft Event Pitch, deg.	
						Significant	Maximum	Double Amplitude or Max-Min[2]	Instantaneous Value[3]
25	4	1	9.6	Boost Off	4.0*	4.0	5.6	5.6	-1.222
10	13	4	24.2	STD	2.5	2.4	4.3	3.6	0.386
9	6	7	48.0	TOS	2.5	2.6	3.4	3.5	0.036
14	20	4	30.8	TOS	4.0*	2.2	3.3	3.2	0.109
25	2	0	5.4	ASE Off	1.5	4.0	5.6	3.1	0.767
11	5	2	15.0	TOS	2.0			2.9	-0.432
25	5	0	8.4	ASE Off	1.0	5.4	5.6	2.7	1.576
10	8	2	15.8	TOS	3.0	2.4	4.3	2.6	0.533
10	10	8	63.4	XDK	4.0*	2.4	4.3	2.6	0.994
14	21	3	25.0	STD	2.5	2.2	3.3	2.3	0.964
10	15	2	15.8	STD	2.0	2.2	3.1	2.3	-0.127
14	16	3	20.8	STD	2.0			2.1	-0.034
11	7	3	21.8	TOS	3.0	2.5	4.1	2.0	-0.032
10	23	2	16.2	TOS	1.5	1.9	2.9	2.0	0.250
11	11	5	31.4	STD	3.0	2.9	4.5	2.0	0.260
14	18	2	20.0	ASE Off	2.0	1.8	2.6	2.0	0.290
11	9	1	11.8	STD	3.0	2.5	4.1	2.0	0.883
23	14	1	11.6	TOS	2.0	3.0	5.5	1.9	0.059
23	12	2	13.2	TOS	2.5			1.9	0.499
23	2	0	13.6	STD	1.5	2.5	3.7	1.8	0.587
13	4	2	25.4	TOS	2.5	1.3	2.0	1.7	0.612
25	7	0	6.4	Boost Off	2.0	4.4	5.3	1.6	0.122
9	4	3	21.2	TOS	2.0	2.4	3.7	1.6	0.369
10	19	2	22.8	TOS	3.0	2.2	4.1	1.6	0.077
23	6	0	9.8	STD	2.0	2.3	3.2	1.5	-0.455
13	12	4	27.2	STD	3.0	1.3	2.1	1.1	0.907
20	14	3	24.8	STD	2.0			1.1	-0.067
16	26	0	11.8	STD	1.5	1.7	2.9	1.1	0.160
10	11	0	2.4	XDK	3.0	2.4	4.3	1.1	0.980
23	16	1	13.6	STD	2.0	2.1	3.2	1.0	1.031

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6B – BOWEN ROLL-VERTICAL LANDING

VL Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State Roll, deg		Aircraft Event Roll, deg.	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
10	10	7	63.4	XDK	4.0*	11.1	15.6	14.6	5.660
10	13	3	24.2	STD	2.5	11.1	15.6	12.8	–0.246
10	19	2	22.8	TOS	3.0	10.2	12.7	12.0	–2.769
9	6	5	48.0	TOS	2.5	7.5	9.8	9.8	0.548
23	2	0	13.6	STD	1.5	8.7	11.0	9.3	–3.267
25	5	0	8.4	ASE Off	1.0	6.9	9.4	9.0	0.812
16	16	0	11.8	ASE Off	1.5	8.9	12.1	8.9	–2.844
25	7	0	6.4	Boost Off	2.0	10.2	12.8	8.3	3.083
23	4	0	19.0	XDK	2.0	8.7	11.0	8.1	2.121
13	4	2	25.4	TOS	2.5	7.3	9.7	8.0	5.259
10	23	1	16.2	TOS	1.5	6.3	10.2	7.2	1.534
23	8	1	14.4	TOS	2.5	12.8	19.2	7.1	3.089
16	5	0	8.4	o	o	8.9	12.1	6.9	6.649
14	20	4	30.8	TOS	4.0*	5.2	6.7	6.5	–3.335
10	15	1	15.8	STD	2.0	10.3	15.7	6.4	3.103
25	4	0	9.6	Boost Off	4.0*	4.4	6.4	6.3	4.187
13	12	2	27.2	STD	3.0	6.3	8.0	6.3	2.641
16	20	0	7.8	STD	1.0	8.3	14.4	6.1	–3.205
10	8	1	15.8	TOS	3.0	11.1	15.6	6.0	4.876
16	14	1	14.2	TOS	1.5	8.3	11.3	5.7	–0.382
23	6	0	9.8	STD	2.0	12.8	19.2	5.5	2.182
13	2	1	16.8	TOS	1.5	6.5	7.2	4.9	0.035
16	2	0	12.0	TOS	1.0	–	–	4.8	–0.539
20	4	1	20.2	STD	1.5	3.0	4.5	4.8	2.133
2	13	0	10.2	TOS	1.5	3.4	5.4	4.8	–1.940
14	18	1	20.0	ASE Off	2.0	4.8	7.3	4.8	1.050
23	14	0	11.6	TOS	2.0	8.7	11.8	4.7	2.871
16	24	1	10.8	STD	1.5	6.0	7.7	4.4	1.566
23	12	1	13.2	TOS	2.5	–	–	4.3	–0.839
16	12	0	10.2	TOS	1.0	8.3	11.3	4.3	0.512

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6C – BOWEN VERTICAL ACCELERATION-VERTICAL LANDING

VL Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State VACC, g's		Aircraft Event VACC, g's	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
10	10	9	63.4	XDK	4.0*	.19	.34	.31	–0.067
25	4	1	9.6	Boost Off	4.0*	.25	.28	.27	0.015
10	13	3	24.2	STD	2.5	.19	.34	.24	–0.025
10	15	2	15.8	STD	2.0	.16	.21	.24	–0.046
9	6	7	48.0	TOS	2.5	.18	.24	.20	–0.029
11	11	5	31.4	STD	3.0	.22	.38	.20	–0.015
11	9	3	21.8	STD	3.0	.19	.32	.20	–0.014
14	20	5	30.8	TOS	4.0*	.13	.19	.17	–0.060
11	5	2	15.0	TOS	2.0	–	–	.17	–0.070
9	4	4	21.2	TOS	2.0	.19	.26	.16	0.016
12	8	2	15.8	TOS	3.0	.19	.34	.15	0.039
14	16	4	20.8	STD	2.0	–	–	.15	–0.067
13	12	4	27.2	STD	3.0	.13	.14	.14	–0.032
16	26	2	11.8	STD	1.5	.13	.20	.14	–0.017
6	11	5	21.8	TOS	2.5	–	–	.14	–0.053
14	18	3	20.0	ASE Off	2.0	.11	.16	.13	0.011
10	16	2	16.2	o	o	.16	.26	.12	0.022
23	11	1	13.2	o	o	.08	.12	.11	–0.022
4	7	3	17.2	TOS	2.0	.08	.13	.11	0.011
25	5	1	8.4	ASE Off	1.0	.23	.28	.11	0.071
14	23	3	20.8	STD	2.0	.12	.18	.10	–0.005
4	3	5	25.8	TOS	2.0	.10	.14	.10	0.005
4	15	2	16.6	TOS	1.0	–	–	.10	–0.008
14	21	4	25.0	STD	2.5	.13	.19	.098	0.002
4	9	3	18.2	TOS	2.0	.08	.13	.095	0.002
10	17	1	15.6	STD	2.0	.12	.20	.092	0.034
20	14	6	24.8	STD	2.0	–	–	.091	–0.007
10	11	0	2.4	XDK	3.0	.19	.34	.090	0.028
6	5	1	15.2	TOS	1.5	.07	.11	.089	–0.010
13	4	4	25.4	TOS	2.5	.09	.12	.087	–0.023

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6D – BOWEN LATERAL ACCELERATION-VERTICAL LANDING

VL Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State LAT ACC, g's		Aircraft Event Pitch	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
9	6	7	48.0	TOS	2.5	.14	.20	.20	–0.005
10	13	4	24.2	STD	2.5	.16	.26	.20	0.017
10	10	10	63.4	XDK	4.0*	.16	.26	.19	–0.029
10	15	2	15.8	STD	2.0	.14	.19	.16	0.025
25	4	2	9.6	Boost Off	4.0*	.11	.23	.15	–0.077
11	11	5	31.4	STD	3.0	.12	.16	.15	0.040
14	20	5	30.8	TOS	4.0*	.09	.14	.12	0.051
25	5	0	8.4	ASE Off	1.0	.10	.14	.11	–0.002
13	12	4	27.2	STD	3.0	.09	.12	.11	–0.010
11	7	4	21.8	TOS	3.0	.10	.15	.11	0.023
10	23	1	16.2	TOS	1.5	.09	.14	.11	–0.010
16	20	1	7.8	STD	1.0	.11	.18	.10	0.003
23	11	1	13.2	o	o	.09	.13	.10	0.018
10	8	2	15.8	TOS	3.0	.16	.26	.10	–0.021
10	19	2	22.8	TOS	3.0	.09	.18	.091	0.00007
23	2	2	13.6	STD	1.5	.07	.10	.091	–0.023
13	4	4	25.4	TOS	2.5	.07	.11	.089	–0.026
4	3	5	25.8	TOS	2.0	.07	.12	.080	0.011
9	4	5	21.2	TOS	2.0	.12	.18	079	0.013
25	7	0	6.4	Boost Off	2.0	.09	.10	.078	–0.032
25	2	0	6.4	ASE Off	1.5	.11	.23	.077	0.036
14	3	3	20.8	TOS	1.0	–	–	.074	0.027
23	2	0	13.6	STD	1.5	.07	.10	.074	0.003
16	14	2	14.2	TOS	1.5	.08	.10	.073	0.009
14	21	4	26.0	STD	2.5	.09	.14	.071	0.014
2	13	1	10.2	TOS	1.5	.04	.08	.068	0.006
16	16	0	11.8	ASE Off	1.5	.08	.11	.066	–0.007
6	11	3	21.8	TOS	2.5	–	–	.064	0.007
10	4	0	2.4	TOS	2.0	.16	.26	.063	0.037
4	15	3	16.6	TOS	1.0	–	–	.063	–0.003

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6E – BOWEN PITCH-VERTICAL TAKEOFF

VTO Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State Pitch, deg.		Aircraft Even Pitch, deg.	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
9	5	0	7.0	TOS	1.0	2.4	3.7	3.1	0.48
25	3	0	6.8	o	o	4.0	5.6	3.0	0.506
23	5	0	12.8	XDK	1.5	2.5	3.7	2.7	1.405
16	25	1	10.0	STD	1.5	1.7	2.9	2.5	0.975
10	9	0	6.6	TOS	1.5	2.4	4.3	2.5	−1.049
11	8	1	10.8	TOS	2.5	2.4	4.1	2.3	0
25	1	1	9.4	STD	1.0	4.0	5.6	2.2	0.199
23	15	0	11.8	TOS	2.0	3.0	5.5	2.2	−0.356
23	7	0	7.6	STD	2.0	2.3	3.2	2.0	−0.568
25	6	0	4.4	o	o	5.4	5.6	2.0	−0.188
9	3	1	10.4	TOS	1.0	2.5	3.6	1.9	0.771
11	4	1	11.8	TOS	2.5	–	–	1.8	0.679
9	7	1	7.0	TOS	1.5	2.6	3.4	1.8	−0.872
23	1	0	12.0	TOS	1.5	2.5	3.7	1.7	−0.740
23	3	1	11.4	TOS	1.5	2.5	3.7	1.7	−0.404
14	22	1	9.2	STD	1.5	2.2	3.3	1.6	0.667
11	10	1	6.8	STD	2.5	2.5	4.1	1.4	0.077
14	19	1	7.4	STD	1.5	1.8	2.6	1.4	0.499
23	9	1	19.4	TOS	2.5	2.3	3.2	1.3	1.031
16	3	0	11.4	TOS	1.0	–	–	1.3	0.051
11	6	1	9.8	TOS	2.5	–	–	1.3	−0.106
9	1	1	8.8	TOS	1.0	2.6	3.6	1.3	0.678
11	2	1	12.6	TOS	1.5	2.1	3.1	1.2	0.616
16	23	2	14.0	STD	1.5	1.7	2.9	1.2	0.056
16	17	0	10.2	STD	1.5	1.1	1.6	1.1	0.654
2	2	2	17.8	TOS	1.0	0.8	1.1	1.1	−0.142
13	1	2	14.2	TOS	1.0	1.2	1.6	1.1	0.659
10	12	0	5.8	XDK	1.5	2.4	4.3	1.0	−0.672
23	13	0	13.2	TOS	1.5	–	–	1.0	0.076
6	10	1	11.0	TOS	1.5	1.0	1.6	1.0	−0.166

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6F – BOWEN ROLL-VERTICAL TAKEOFF

VTO Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State Roll, deg.		Aircraft Event Roll, deg.	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
23	1	0	12.0	TOS	1.5	8.7	11.0	9.3	−1.112
10	12	0	5.8	XDK	1.5	11.1	15.6	9.3	7.577
23	5	0	12.8	XDK	1.5	8.7	11.0	9.1	−1.780
23	9	1	19.4	TOS	2.5	12.8	19.2	8.6	2.176
9	1	0	8.8	TOS	1.0	6.6	8.8	8.2	−0.737
10	9	0	6.6	TOS	1.5	11.1	15.6	7.8	6.513
23	7	0	7.6	STD	2.0	12.8	19.2	7.5	−1.773
23	15	1	11.8	TOS	2.0	8.7	11.8	5.9	5.033
16	17	0	10.2	STD	1.5	8.9	12.1	5.6	−3.471
16	21	1	12.8	STD	2.0	8.3	14.4	5.6	1.828
23	13	0	13.2	TOS	1.5	–	–	5.5	1.725
13	5	1	12.4	TOS	1.5	7.3	9.7	5.5	−0.903
10	20	0	12.4	TOS	2.0	10.2	12.7	5.4	3.199
16	25	0	10.6	STD	1.5	6.0	7.6	5.4	−3.949
16	1	0	9.4	TOS	1.5	–	–	5.4	1.105
13	11	0	12.8	STD	1.5	6.6	9.0	5.3	2.703
13	9	1	7.2	STD	2.5	5.8	7.1	5.1	3.047
10	14	0	9.4	STD	1.0	10.3	15.7	5.1	4.931
10	18	1	9.4	STD	2.0	10.2	12.7	4.7	0.750
9	9	0	7.0	TOS	1.5	7.5	9.8	4.6	3.595
25	6	0	4.4	o	o	6.9	9.4	4.4	−1.541
10	16	0	8.8	STD	1.0	10.3	15.7	4.4	3.280
16	27	1	11.8	STD	1.0	6.0	7.6	4.3	−1.262
16	13	0	12.2	TOS	2.0	8.3	11.3	4.2	1.262
4	12	0	7.4	TOS	2.0	4.0	6.0	4.2	1.108
14	19	0	7.4	STD	1.5	4.8	7.3	4.2	−3.219
4	20	0	9.8	TOS	1.5	4.9	7.9	4.1	−4.146
20	13	0	8.4	STD	1.5	–	–	4.1	−2.398
4	8	0	8.4	TOS	2.0	4.0	7.2	4.0	−2.935
16	3	0	11.4	TOS	1.0	–	–	3.9	−1.064

NOTE: See footnotes at the bottom of Table 6g and Table 6h.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6G – BOWEN VERTICAL ACCELERATION-VERTICAL TAKEOFF

VTO Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State VACC, g's		Aircraft Event VACC, g's	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
25	3	0	6.8	o	o	.25	.28	.22	−0.086
10	12	0	5.8	XDK	1.5	.19	.34	.20	−0.076
9	7	0	7.0	TOS	1.5	.18	.24	.19	−0.125
25	1	1	9.4	STD	1.0	.25	.28	.18	−0.018
10	16	1	8.8	STD	1.0	.16	21	.15	0.060
11	8	1	10.8	TOS	2.5	.19	.32	.13	−0.023
16	25	1	10.0	STD	1.5	.13	.20	.13	0.046
9	1	1	8.8	TOS	1.0	.15	.27	.12	0.014
16	27	1	11.8	STD	1.0	.13	.20	.11	0.009
10	18	0	9.4	STD	2.0	.12	.20	11	−0.014
16	21	1	12.8	STD	2.0	.17	.27	.11	−0.059
9	5	1	7.0	TOS	1.0	.19	.26	.10	−0.016
11	4	2	11.8	TOS	2.5	–	–	.10	−0.005
14	19	1	7.4	STD	1.5	.11	.16	.099	0.031
11	10	0	6.8	STD	2.5	.19	.32	.099	0.021
13	1	2	14.2	TOS	1.0	.08	.11	.093	0.022
10	9	0	6.6	TOS	1.5	–	–	.093	−0.045
23	1	2	11.8	TOS	1.5	.05	.08	.091	−0.006
10	14	1	9.4	STD	1.0	.16	.21	.091	0.007
16	19	1	10.2	STD	1.0	.11	.15	.089	−0.026
10	20	1	12.4	TOS	2.0	.12	.20	.087	0.029
13	13	1	7.8	STD	1.5	.13	.14	.086	−0.016
4	14	1	8.2	TOS	1.5	.10	.14	.083	−0.018
16	23	2	14.0	STD	1.5	.13	.20	.082	−0.013
2	2	3	17.8	TOS	1.0	.06	.11	.079	−0.032
9	3	1	10.4	TOS	1.0	.15	.27	.078	0.011
23	7	0	7.6	STD	2.0	.08	.12	.076	0.012
11	2	2	12.6	TOS	1.5	.11	.16	.075	0.031
4	16	2	8.2	TOS	1.0	–	–	.073	0.010
14	17 (4)	1	6.0	STD	1.5	–	–	.069	−0.016

1. [1]Cycle defined by three successive zero crossings.

2. [2]Aircraft event data defined in Figure 1, and page 6. If event contains one or more motion cycles, the largest double amplitude is recorded; if event contains less than one motion cycle, the difference between the largest (max.) positive and lowest minimum (min.), i.e., max-min for event, is recorded.

3. [3]See Figure 1 and page 6 for definitions

4. *Designates Waveoff, see page 21.

5. –Designates events that occured before ship had stabilized from speed or heading change. These values not graphed in Figures 13 & 14.

TABLE 6 – ORDERED VALUES FROM WHICH FIGURES 13 AND 14 WERE PREPARED

TABLE 6H – BOWEN LATERAL ACCELERATION-VERTICAL TAKEOFF

VTO Run No.	Event No.	No. Cycles	Time Sec.	Type of Event	Pilot Rating PRS	Steady State LAT ACC, g's		Aircraft Event LAT ACC, g's	
						Significant	Maximum	Double Amplitude or Max-Min	Instantaneous Value
10	12	0	5.8	XDK	1.5	.16	.26	.16	–0.069
25	3	0	6.8	o	o	.11	.23	.12	–0.004
10	16	2	8.8	STD	1.0	.14	.19	.11	–0.005
9	1	0	8.8	TOS	1.0	.10	.14	.10	0.043
10	9	1	6.6	TOS	1.5	.16	.26	.096	–0.056
16	15	0	7.8	TOS	1.0	.08	.10	.091	0.024
23	5	0	12.8	XDK	1.5	.07	.10	.091	–0.007
16	21	1	12.8	STD	2.0	.11	.18	.083	0.018
9	9	0	7.0	TOS	1.5	.14	20	.079	–0.0008
9	5	1	7.0	TOS	1.0	.12	.18	.079	–0.003
23	1	0	12.0	TOS	1.5	.07	.10	.078	0.004
23	12	3	13.2	o	o	–	–	.074	0.012
25	6	0	4.4	o	o	.10	.14	.073	0.033
16	3	1	11.4	TOS	1.0	–	–	.073	0.034
25	1	1	9.4	STD	1.0	.11	.23	.072	0.036
16	25	1	10.0	STD	1.5	.08	.18	.071	0.038
10	14	1	9.4	STD	1.0	.14	.19	.068	–0.010
10	18	0	9.4	STD	2.0	.09	.18	.066	0.014
23	7	0	7.6	STD	2.0	.09	.13	.061	0.022
13	9	2	7.2	STD	2.5	.06	.08	.060	–0.025
13	5	2	12.4	TOS	1.5	.07	.11	.059	–0.007
11	2	2	12.6	TOS	1.5	.06	.08	.059	0.032
13	13	1	7.8	STD	1.5	.09	.12	.059	0.005
23	1	2	11.8	TOS	1.5	.05	.08	.059	–0.029
10	22	0	3.2	STD	1.0	.09	.14	.057	–0.010
13	11	0	12.8	STD	2.5	.05	.06	.054	–0.00003
4	12	1	7.4	TOS	2.0	.05	.08	.052	0.019
11	10	0	6.8	STD	2.5	.10	.16	.051	0.008
6	10	1	11.0	TOS	1.5	.06	.11	.050	0.002
14	17	0	6.0	STD	1.5	–	–	.050	0.009

6. °Designates unavailable aircraft information.

7. ASE off - Automatic Stabilization Equipment (Yaw), disengaged.

8. Boost off - Hydraulic Control Boost, disengaged.

9. XDK - Cross-deck landing or takeoff. Not recommended for fleet use.

10. TOS - Turn on the Spot, modified landing or takeoff.

11. STD - Standard landing or takeoff.